臺灣總督府

# 農業試驗所報告

第七十五號

---

## 稻ノ開花ニ關スル研究

---

臺灣總督府農業試驗所

昭和十五年七月

REPORT No. 75 July, 1940

GOVERNMENT AGRICULTURAL RESEARCH INSTITUTE
TAIWAN, NIPPON (JAPAN)

Prof. KISABURO SHIBUYA, *Director*

---

# A CONTRIBUTION TO THE KNOWLEDGE OF BLOOMING IN RICE FLOWERS

BY

IWAO KAMO

---

PUBLISHED BY THE INSTITUTE
TAIHOKU, TAIWAN

REPORT No. 75 July, 1940

GOVERNMENT AGRICULTURAL RESEARCH INSTITUTE
TAIWAN, NIPPON (JAPAN)

Prof. KISABURO SHIBUYA, *Director*

---

# A CONTRIBUTION TO THE KNOWLEDGE OF BLOOMING IN RICE FLOWERS

BY

IWAO KAMO

---

PUBLISHED BY THE INSTITUTE
TAIHOKU, TAIWAN

The organization of the Government Research Institute, Formosa, heretofore, was consisted of four Departments of Agriculture, Forestry, Industry and Hygienics, has been superseded by the new Institutes which are independent each other, in accordance with the provisions of Imperial Ordinance No. 275 April 27th, 1939.

The new Government Agricultural Research Institute will continue to pursue and develope experimental and research works in Agriculture.

With regard to the publications formerly issued by the Department of Agriculture, Government Research Institute, the series will be continued without interruption but will bear the title of the new Institute.

From the point of view of national food-production, rice is undoubtedly the most important crop raised in Japan.

Thanks to the active research work carried out by our investigators, the science of agriculture has made great progress in recent years more especially as regards increasing and improving the annual yield of rice.

The author of the present study has recently discovered some vitally significant facts concerning the hastening influence of light upon the blooming time of the rice flower. According to the results of his researches, the period of blooming may be controlled to a hitherto unsuspected extent by a sudden weakening of the light or by transferring the plants inside a shelter several hours before the natural time of blooming.

There is every reason to believe, therefore, that the practical application of the author's experimental findings to the technique of artificial cross-breeding, will make a very notable contribution to the breeding processes of rice varieties.

Prof. Dr. KISABURO SHIBUYA

Director

# CONTENTS


| | | Page |
|---|---|---|
| I. | Introduction. ... ... ... ... ... ... ... ... ... ... ... ... ... | 1 |
| II. | Experiments on the artificial hastening of blooming in rice flowers. | 2 |
| 1. | Blooming phenomena in rice flowers in cases where the plants were transferred from the outside to the inside of the house. | 2 |
| (1) | Materials and methods. ... ... ... ... ... ... ... ... ... | 2 |
| (2) | Results of the experiments. ... ... ... ... ... ... ... ... | 3 |
| (3) | Considerations on the mechanism of hastening by means of transference. ... ... ... ... ... ... ... ... ... ... ... ... | 19 |
| *a*) | Relation between the temperature and the blooming... | 19 |
| *b*) | Relation between the humidity and the blooming. ... | 24 |
| *c*) | Relation between the change of light and the blooming. | 31 |
| *d*) | Relation between the environmental conditions preceding transference and the blooming. ... ... ... ... ... | 37 |
| 2. | Blooming phenomena in rice flowers subjected to unusually high temperature ... ... ... ... ... ... ... ... ... ... ... | 40 |
| 3. | Blooming phenomena in rice flowers due to mechanical stimulation. ... ... ... ... ... ... ... ... ... ... ... ... ... | 42 |
| (1) | Relation between the rubbing of the panicle and the blooming. ... ... ... ... ... ... ... ... ... ... ... ... | 42 |
| (2) | Relation between the shaking of the panicle and the blooming. ... ... ... ... ... ... ... ... ... ... ... | 44 |
| 4. | Indehiscence of anthers in artificially hastened blooming flowers. ... ... ... ... ... ... ... ... ... ... ... ... ... ... | 47 |
| III. | Experimental studies on some environmental factors affecting the natural blooming time of rice flowers. ... ... ... ... ... ... ... | 52 |
| 1. | Effect of light upon time of blooming. ... ... ... ... ... ... | 52 |
| 2. | Effect of temperature upon time of blooming. ... ... ... ... | 64 |
| 3. | Effect of humidity upon time of blooming. ... ... ... ... ... | 71 |
| IV. | Physical mechanism of the opening of rice flowers. ... ... ... ... | 73 |
| 1. | Change in size of the lodicules. ... ... ... ... ... ... ... ... | 73 |
| 2. | Separation of the hooked glumes and their opening. ... ... | 76 |
| (1) | Separation of the hooked glumes. ... ... ... ... ... ... | 77 |
| (2) | Opening of the glumes. ... ... ... ... ... ... ... ... ... | 81 |
| 3. | Relation between the elongation of filament and the blooming. | 82 |

Page

V. Application of artificial blooming with indehiscent anthers to crossing technique. ... ... ... ... ... ... ... ... ... ... ... ... 84
1. Method of emasculation. ... ... ... ... ... ... ... ... ... 86
2. Emasculation by the new method and self-fertilization. ... ... 87
3. Results of crossing by the new emasculation method. ... ... 88
4. The new emasculation method and the preservation of conceptive potency of the stigma. ... ... ... ... ... ... ... ... 90
VI. Discussion. ... ... ... ... ... ... ... ... ... ... ... ... ... ... 91
VII. Summary. ... ... ... ... ... ... ... ... ... ... ... ... ... ... 99
VIII. Literature cited. ... ... ... ... ... ... ... ... ... ... ... ... ... 104
Appendix. ... ... ... ... ... ... ... ... ... ... ... ... ... ... 107

# A CONTRIBUTION TO THE KNOWLEDGE OF BLOOMING IN RICE FLOWERS

By

Iwao KAMO

## I. INTRODUCTION

The study of blooming in cereals is not only interesting from the point of view of crop science but also very important and necessary viewed from the plant breeding standpoint. Consequently many works have been published on this subject. Those who have studied the blooming phenomena of rice flowers in detail are AKEMINE (1914) and NOGUCHI (1929) and many other authors in Japan, British India, Philippine as well as America might also be mentioned. Indeed it goes without saying that there is scarcely any further room for general investigations on the blooming of rice flowers under natural conditions.

The time of blooming during the day is affected by weather conditions and also is variable according to seasons and districts; generally speaking, however, it begins about 9 a.m. and most of the flowers for the day bloom between 10 a.m. and 12 noon, as shown by the results of many investigations. In this respect the rice plant differs from other important cereals such as wheat, barley, rye and oats.

Recently the author has observed that when the rice panicle is transferred from the field to the inside of the house early in the morning, the flower begins to open much earlier than it does out-of-doors (KAMO 1938-b). The analogous phenomenon has already been reported by RAMIAH (1927). It is very interesting and important to explain by what mechanism this phenomenon takes place. Starting from here the author has carried out some experimental studies on the blooming and related phenomena in rice flowers since 1935 and a part of the experiments was preliminarily reported in 1938. In this paper he dealt with the results of investigations chiefly on: (1) artificial hastening of blooming, (2) blooming phenomena in relation to the environmental factors, and (3) physical mechanism of the opening of glumes.

It is a pleasure to acknowledge the invaluable encouragement and the facilities given to the author during this investigation by Prof. Kisaburo SHIBUYA, the Director. The author wishes to express his gratitude to Prof. Eikichi Iso for his cordial guidance throughout the course of this work. The author's thanks are also due to Hon. Prof. Masao AKEMINE, Prof. Torao TESHIMA and Prof. Seijin NAGAO for their invaluable criticisms and help. Moreover, the author desires in particular to express his heartiest thanks to Dr. Tsunetoshi SHIBUYA for his kind advice and continuous encouragement. Finally the author is very much indebted to Mr. Yoshinori TAHARA for much help in his experimental work.

## II. EXPERIMENTS ON THE ARTIFICIAL HASTENING OF BLOOMING IN RICE FLOWERS

### 1. *Blooming phenomena in rice flowers in cases where the plants were transferred from the outside to the inside of the house*

When the panicle of rice plant is transferred a little before its natural blooming time from the field into the crossing room (an ordinary house with glass windows on the three side) in order to obtain the pollen for artificial crossing, the author has often experienced a failure in carrying out his purpose, because the flowers used to begin opening soon after the transference into the room and the anthers remain indehiscent. While at first the author had presumed that the hastening of blooming might be only a physiological phenomenon abnormally introduced by the cutting of the panicle, he later ascertained that this phenomenon does only occur in the cases where the cut panicles are transferred to the inside of the house. Similar facts are also observable if the plant in a pot is transferred to the inside of the house without cutting its panicle. The results of observations and experiments will be mentioned in detail in subsequent paragraphs.

#### (1) Materials and methods

The varieties of rice used for this experiment are Taichu No. 65, Aikoku, Kameji, Shinriki, Asahi and Taino No. 22. All the materials used were transplanted into pots at least two days before the experiments were carried out and were kept in a given place. In every pot one plant was cultivated, and panicles which were healthy and uniform in their growth carefully chosen. The place where the materials were kept was the north-western side of the

house in which the experiments were carried out. In that place the material plants were not exposed to the direct rays of the sun until about 11 a.m. The expression "outside" in the following descriptions refers to this place. The panicles for the experiments were numbered in the afternoon of the previous day and every flower that had already bloomed was cut off. The transference of plants from outside to inside of the house was done every morning between 6 or 7 a.m. and 9 or 10 a.m.* with intervals of half an hour (in Experiments I and II) or one hour, and then the time of first blooming in each panicle and the number of blooming flowers in every given time were noted. The anthers of each flower were removed soon after the blooming in order to avoid confusion with later bloomings.

### (2) Results of the experiments

The results of the experiments carried out are shown in Table 1.

It is quite clearly shown from Table 1, that the time of blooming in rice flowers may be stepped up artificially by means of the transference of the panicle from the outside to the inside of the house: in the control plot the first blooming occurs about at 9 a.m., while if the panicles are transferred into the house, flowers are able to begin blooming at 7 or even at 6 a.m. When they are transferred too early in the morning, however, the hastening phenomenon does not occur. The earliest time of transference which is fully effective for hastening the blooming may be different in different varieties. According to the results of the transference experiments, it may be said that the blooming begins to occur about 7 a.m. in the varieties Aikoku, Kameji, Asahi and Taino No. 22 respectively and in Taichu No. 65 about 6 a.m.

It is quite natural to consider that these hours should vary with the environmental conditions, especially weather and season. The author has not infrequently experienced during the experiments that the hastening of blooming is often suppressed under unfavourable weather conditions. Especially in a case where the weather conditions are extremely bad, no hastening may take place. As for seasonal differences, the results of experiments shown in Tables 1 and 5 should be referred to. It is possible to see that the time of the first

* The time referred to in the present work is the old Formosan time which is one hour earlier than the present standard time which was introduced on Oct. 1st., 1937. As most of the experiments in this work were made according to the old time, he has used it without amendment. Therefore 6 a.m. in this work, for example, corresponds to 7 a.m. (Japan standard time).

TABLE 1.

The hastening of blooming in rice flowers by means of transference from the outside to the inside of the house.

Experiment I.

(June 11, 1935. Weather: fine. Variety: Taichu No. 65.)

| Time of transference of plants from outside to inside the house | Time when blooming begins | Number of blooming flowers in the given time | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | —7.10 a.m. | 7.20 a.m. | 7.30 a.m. | 8.00 a.m. | 9.00 a.m. | 10.00 a.m. | 11.00 a.m. | 12.00 m. | 1.00 p.m. | 2.00 p.m. | 3.00 p.m. | Total |
| 7.00 a.m. | Panicle I 7.04 a.m. | 4 | 2 | 0 | 0 | 0 | 0 | 0 | 2 | 9 | 1 | 0 | 18 |
| | " II 7.04 a.m. | 3 | 0 | 0 | 3 | 0 | 0 | 0 | 3 | 12 | 6 | 0 | 27 |
| | | —7.40 | 7.50 | 8.00 | 8.30 | 9.30 | 10.30 | 11.30 | 12.30 | 2.00 | 3.00 | | Total |
| 7.30 a.m. | Panicle I 7.37 a.m. | 9 | 3 | 0 | 2 | 0 | 0 | 0 | 3 | 0 | 0 | | 17 |
| | " II 7.37 a.m. | 6 | 3 | 1 | 1 | 0 | 0 | 0 | 11 | 1 | 0 | | 23 |
| | | —8.10 | 8.20 | 8.30 | 9.00 | 10.00 | 11.00 | 12.00 | 1.00 | 2.00 | 3.00 | | Total |
| 8.00 a.m. | Panicle I 8.05 a.m. | 14 | 2 | 1 | 2 | 1 | 0 | 0 | 2 | 0 | 0 | | 22 |
| | " II 8.05 a.m. | 7 | 1 | 7 | 3 | 3 | 0 | 6 | 4 | 2 | 0 | | 33 |
| | | —8.40 | 8.50 | 9.00 | 9.30 | 10.30 | 11.30 | 12.30 | 2.00 | 3.00 | | | Total |
| 8.30 a.m. | Panicle I 8.35 a.m. | 19 | 1 | 0 | 4 | 3 | 0 | 0 | 1 | 0 | | | 28 |
| | " II 8.35 a.m. | 9 | 1 | 0 | 0 | 0 | 0 | 3 | 1 | 0 | | | 14 |
| | | —9.10 | 9.20 | 9.30 | 10.00 | 11.00 | 12.00 | 1.00 | 2.00 | 3.00 | | | Total |
| 9.00 a.m. | Panicle I 9.04 a.m. | 8 | 2 | 2 | 4 | 1 | 4 | 7 | 0 | 0 | | | 28 |
| | " II 9.05 a.m. | 11 | 0 | 1 | 4 | 1 | 3 | 2 | 0 | 0 | | | 22 |
| | | —9.40 | 9.50 | 10.00 | 10.30 | 11.30 | 12.30 | 2.00 | 3.00 | | | | Total |
| 9.30 a.m. | Panicle I 9.34 a.m. | 14 | 0 | 0 | 0 | 1 | 1 | 1 | 0 | | | | 17 |
| | " II 9.36 a.m. | 4 | 4 | 1 | 0 | 0 | 7 | 0 | 0 | | | | 16 |
| | | —10.10 | 10.20 | 10.30 | 11.00 | 12.00 | 1.00 | 2.00 | 3.00 | | | | Total |
| 10.00 a.m. | Panicle I 10.02 a.m. | 19 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | | | | 21 |
| | " II 10.02 a.m. | 21 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | | | | 22 |
| | | —10.30 | 11.00 | 11.30 | 12.00 | 12.30 | 1.00 | 2.00 | 3.00 | | | | Total |
| Control (Outside) | Panicle I 10.14 a.m. | 3 | 21 | 0 | 0 | 0 | 0 | 0 | 0 | | | | 24 |
| | " II 10.03 a.m. | 9 | 16 | 1 | 0 | 0 | 0 | 0 | 0 | | | | 26 |

TABLE 1.
(Continued)
Experiment II.
(June 13, 1935. Weather: cloudy. Variety: Taichu No. 65.)

| Time of transference of plants from outside to inside the house | Time when blooming begins | | Number of blooming flowers in the given time |
|---|---|---|---|
| 7.00 a.m. | | | —7.10 a.m. — 7.20 a.m. — 7.30 a.m. — 8.00 a.m. — 8.30 a.m. — 9.00 a.m. — 9.30 a.m. — 10.00 a.m. — 10.30 a.m. — 11.00 a.m. — 11.30 a.m. — 12.00 m. — 12.30 p.m. — 1.00 p.m. — 1.30 p.m. — 2.00 p.m. — 3.00 p.m. Total |
| | Panicle I | 7.07 a.m. | 4 2 0 0 0 1 0 1 0 0 0 2 2 4 0 0 0 16 |
| | „ II | 7.07 a.m. | 4 3 0 0 1 1 0 0 2 0 1 2 3 7 1 0 0 25 |
| 7.30 a.m. | | | —7.10 — 7.50 — 8.00 — 8.30 — 9.00 — 9.30 — 10.00 — 10.30 — 11.00 — 11.30 — 12.00 — 12.30 — 1.00 — 1.30 — 2.00 — 3.00 Total |
| | Panicle I | 7.36 a.m. | 9 6 0 0 2 0 0 0 0 0 1 0 1 0 1 0 20 |
| | „ II | 7.36 a.m. | 6 5 0 1 0 0 0 0 0 0 5 0 3 0 0 0 20 |
| 8.00 a.m. | | | —8.10 — 8.20 — 8.30 — 9.00 — 9.30 — 10.00 — 10.30 — 11.00 — 11.30 — 12.00 — 12.30 — 1.00 — 1.30 — 2.00 — 3.00 Total |
| | Panicle I | 8.10 a.m. | 1 1 2 0 1 0 1 1 1 1 1 2 6 0 0 18 |
| | „ II | 8.09 a.m. | 2 4 2 2 1 0 1 0 1 3 3 1 1 0 0 21 |
| 8.30 a.m. | | | —8.40 — 8.50 — 9.00 — 9.30 — 10.00 — 10.30 — 11.00 — 11.30 — 12.00 — 12.30 — 1.00 — 1.30 — 2.00 — 3.00 Total |
| | Panicle I | 8.35 a.m. | 5 2 0 0 2 0 0 0 0 0 0 1 0 0 10 |
| | „ II | 8.35 a.m. | 6 4 1 0 0 1 1 0 0 1 0 0 0 0 14 |
| 9.00 a.m. | | | —9.10 — 9.20 — 9.30 — 10.00 — 10.30 — 11.00 — 11.30 — 12.00 — 12.30 — 1.00 — 1.30 — 2.00 — 3.00 Total |
| | Panicle I | 9.24 a.m. | 0 0 1 0 1 3 0 7 2 1 7 1 0 23 |
| | „ II | 9.15 a.m. | 0 1 1 2 0 2 1 9 4 2 1 0 0 23 |
| 9.30 a.m. | | | —9.40 — 9.50 — 10.00 — 10.30 — 11.00 — 11.30 — 12.00 — 12.30 — 1.00 — 1.30 — 2.00 — 3.00 Total |
| | Panicle I | 9.36 a.m. | 16 1 0 0 0 0 0 0 0 0 0 0 17 |
| | „ II | 9.36 a.m. | 10 1 0 0 1 0 1 2 0 1 0 0 16 |
| 10.00 a.m. | | | —10.10 — 10.20 — 10.30 — 11.00 — 11.30 — 12.00 — 12.30 — 1.00 — 1.30 — 2.00 — 3.00 Total |
| | Panicle I | 10.05 a.m. | 19 4 2 1 0 0 0 1 0 0 0 27 |
| | „ II | 10.04 a.m. | 19 2 1 3 1 0 0 0 1 1 0 28 |
| Control (Outside) | | | —11.00 — 11.30 — 12.00 — 12.30 — 1.00 — 1.30 — 2.00 — 3.00 Total |
| | Panicle I | 11.03 a.m. | 0 22 2 0 0 0 0 0 24 |
| | „ II | 10.50 a.m. | 1 14 0 0 1 0 0 0 16 |

TABLE 1.

(Continued)

Experiment III.

(June 12, 1936. Weather: fine. Variety: Taichu No. 65.)

| Time of transference of plants from outside to inside the house | Time when blooming begins | Number of blooming flowers in the given time | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | —8.00 a.m. | —9.00 a.m. | —10.00 a.m. | —11.00 a.m. | —12.00 m. | —1.00 p.m. | —2.00 p.m. | —3.00 p.m. | Total |
| 7.00 a.m. | Panicle I 7.05 a.m. | 5 | 0 | 0 | 0 | 12 | 7 | 0 | 0 | 24 |
| | „ II 7.16 a.m. | 7 | 1 | 0 | 0 | 6 | 7 | 4 | 0 | 25 |
| 8.00 a.m. | Panicle I 8.05 a.m. | | 9 | 0 | 1 | 3 | 1 | 0 | 0 | 14 |
| | „ II 8.04 a.m. | | 9 | 0 | 0 | 3 | 1 | 0 | 0 | 13 |
| 9.00 a.m. | Panicle I 9.06 a.m. | | | 15 | 1 | 2 | 3 | 0 | 0 | 21 |
| | „ II 9.04 a.m. | | | 16 | 0 | 4 | 5 | 0 | 0 | 25 |
| Control (Outside) | Panicle I 9.36 a.m. | | | 2 | 1 | 15 | 0 | 0 | 0 | 18 |
| | „ II 9.37 a.m. | | | 1 | 1 | 11 | 0 | 0 | 0 | 13 |
| Control (Inside) | Panicle I 10.45 a.m. | | | | 3 | 23 | 1 | 0 | 0 | 27 |
| | „ II 11.24 a.m. | | | | 0 | 22 | 1 | 0 | 0 | 23 |

Note: "Control (Inside)" means the material kept inside the house from the previous day.

TABLE 1.
(Continued)
Experiment IV.
(June 14, 1936. Weather: fine. Variety: Taichu No. 65.)

| Time of transference of plants from outside to inside the house | Time when blooming begins | Number of blooming flowers in the given time | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | —7.00 a.m. | —8.00 a.m. | —9.00 a.m. | —10.00 a.m. | —11.00 a.m. | —12.00 m. | —1.00 p.m. | —2.00 p.m. | —3.00 p.m. | Total |
| 6.00 a.m. | Panicle I 6.20 a.m. | 2 | 0 | 0 | 0 | 1 | 1 | 16 | 3 | 0 | 23 |
| | „ II 12.02 p.m. | | | | | | | 21 | 3 | 0 | 24 |
| 7.00 a.m. | Panicle I 7.11 a.m. | | 5 | 3 | 5 | 1 | 0 | 17 | 1 | 0 | 32 |
| | „ II 7.34 a.m. | | 1 | 3 | 1 | 0 | 1 | 18 | 0 | 2 | 26 |
| 8.00 a.m. | Panicle I 8.04 a.m. | | | 22 | 3 | 3 | 1 | 2 | 3 | 0 | 34 |
| | „ II 8.04 a.m. | | | 25 | 2 | 0 | 0 | 5 | 0 | 0 | 32 |
| 9.00 a.m. | Panicle I 9.03 a.m. | | | | 28 | 1 | 0 | 0 | 0 | 0 | 29 |
| | „ II 9.04 a.m. | | | | 20 | 1 | 0 | 0 | 0 | 0 | 21 |
| Control (Outside) | Panicle I 9.53 a.m. | | | | 3 | 5 | 24 | 2 | 0 | 0 | 34 |
| | „ II 11.32 a.m. | | | | | | 18 | 1 | 10 | 0 | 29 |
| Control (Inside) | Panicle I 11.38 a.m. | | | | | | 3 | 34 | 0 | 0 | 37 |
| | „ II 11.40 a.m. | | | | | | 1 | 18 | 0 | 0 | 19 |

TABLE 1.

(Continued)

Experiment V.

(June 15, 1936. Weather: fine. Variety: Taichu No. 65.)

| Time of transference of plants from outside to inside the house | Time when blooming begins | Number of blooming flowers in the given tin. | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | —7.00 a.m. | —8.00 a.m. | —9.00 a.m. | —10.00 a.m. | —11.00 a.m. | —12.00 m. | —1.00 p.m. | —2.00 p.m. | —3.00 p.m. | Total |
| 6.00 a.m. | Panicle I 6.10 a.m. | 5 | 0 | 1 | 2 | 0 | 0 | 7 | 7 | 2 | 24 |
| | " II 6.14 a.m. | 2 | 2 | 2 | 0 | 0 | 0 | 1 | 10 | 6 | 23 |
| 7.00 a.m. | Panicle I 7.08 a.m. | | 6 | 1 | 2 | 0 | 1 | 4 | 6 | 9 | 29 |
| | " II 7.11 a.m. | | 8 | 0 | 1 | 1 | 1 | 1 | 9 | 9 | 30 |
| 8.00 a.m. | Panicle I 8.05 a.m. | | | 15 | 0 | 0 | 0 | 2 | 4 | 2 | 23 |
| | " II 8.05 a.m. | | | 17 | 1 | 0 | 0 | 0 | 3 | 2 | 23 |
| 9.00 a.m. | Panicle I 9.03 a.m. | | | | 26 | 0 | 0 | 1 | 3 | 0 | 30 |
| | " II 9.04 a.m. | | | | 16 | 2 | 0 | 1 | 1 | 0 | 20 |
| Control (Outside) | Panicle I 10.44 a.m. | | | | | 12 | 10 | 9 | 1 | 0 | 32 |
| | " II 10.20 a.m. | | | | | 12 | 8 | 5 | 0 | 0 | 25 |
| Control (Inside) | Panicle I 1.14 p.m. | | | | | | | | 11 | 8 | 19 |
| | " II 1.54 p.m. | | | | | | | | 2 | 12 | 14 |

TABLE 1.
(Continued)
Experiment VI.
(May 25, 1936. Weather: fine. Variety: Aikoku.)

| Time of transference of plants from outside to inside the house | Time when blooming begins | Number of blooming flowers in the given time | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | —7.00 a.m. | —8.00 a.m. | —9.00 a.m. | —10.00 a.m. | —11.00 a.m. | —12.00 m. | —1.00 p.m. | —2.00 p.m. | —3.00 p.m. | Total |
| 6.00 a.m. | Panicle I 12.24 p.m. | | | | | | | 10 | 4 | 0 | 14 |
| | „ II 12.25 p.m. | | | | | | | 9 | 2 | 0 | 11 |
| 7.00 a.m. | Panicle I 9.26 a.m. | | | | 1 | 0 | 0 | 6 | 0 | 4 | 11 |
| | „ II 7.24 a.m. | | 1 | 0 | 0 | 0 | 0 | 8 | 1 | 1 | 11 |
| 8.00 a.m. | Panicle I 9.03 a.m. | | | | 1 | 0 | 0 | 15 | 0 | 0 | 16 |
| | „ II 8.44 a.m. | | | 1 | 1 | 0 | 0 | 7 | 0 | 0 | 9 |
| 9.00 a.m. | Panicle I 9.09 a.m. | | | | 11 | 1 | 0 | 0 | 1 | 1 | 14 |
| | „ II 9.09 a.m. | | | | 12 | 0 | 3 | 3 | 0 | 0 | 18 |
| Control (Outside) | Panicle I 9.15 a.m. | | | | 1 | 4 | 5 | 4 | 2 | 0 | 16 |
| | „ II 10.15 a.m. | | | | | 3 | 7 | 2 | 2 | 0 | 14 |
| Control (Inside) | Panicle I 12.30 p.m. | | | | | | | 6 | 5 | 0 | 11 |
| | „ II 11.25 a.m. | | | | | | 12 | 10 | 0 | 0 | 22 |

TABLE 1.

(Continued)

Experiment VII.

(June 4, 1936. Weather: fine. Variety: Kameji.)

| Time of transference of plants from outside to inside the house | Time when blooming begins | Number of blooming flowers in the given time | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | —7.00 a.m. | —8.00 a.m. | —9.00 a.m. | —10.00 a.m. | —11.00 a.m. | —12.00 m. | —1.00 p.m. | —2.00 p.m. | —3.00 p.m. | Total |
| 6.00 a.m. | Panicle I 11.40 a.m. | | | | | | 1 | 11 | 3 | 0 | 15 |
| | „ II 12.40 p.m. | | | | | | | 10 | 6 | 1 | 17 |
| 7.00 a.m. | Panicle I 8.35 a.m. | | | 1 | 0 | 1 | 3 | 10 | 6 | 2 | 23 |
| | „ II 7.36 a.m. | | 1 | 1 | 2 | 0 | 3 | 6 | 5 | 0 | 18 |
| 8.00 a.m. | Panicle I 8.07 a.m. | | | 8 | 1 | 0 | 0 | 5 | 3 | 1 | 18 |
| | „ II 8.08 a.m. | | | 10 | 3 | 3 | 1 | 6 | 2 | 1 | 26 |
| 9.00 a.m. | Panicle I 9.03 a.m. | | | | 19 | 0 | 1 | 0 | 4 | 0 | 24 |
| | „ II 9.03 a.m. | | | | 19 | 0 | 0 | 2 | 2 | 0 | 23 |
| 10.00 a.m. | Panicle I 10.03 a.m. | | | | | 22 | 0 | 0 | 0 | 0 | 22 |
| | „ II 10.03 a.m. | | | | | 21 | 1 | 0 | 0 | 0 | 22 |
| Control (Outside) | Panicle I 11.02 a.m. | | | | | | 24 | 0 | 0 | 0 | 24 |
| | „ II 11.01 a.m. | | | | | | 24 | 2 | 0 | 0 | 26 |
| Control (Inside) | Panicle I 12.36 p.m. | | | | | | | 3 | 19 | 3 | 25 |
| | „ II 12.40 p.m. | | | | | | | 2 | 17 | 7 | 26 |

TABLE 1.

(Continued)

Experiment VIII.

(June 8, 1936. Weather: cloudy. Variety: Shinriki.)

| Time of transference of plants from outside to inside the house | Time when blooming begins | Number of blooming flowers in the given tim | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | —8.00 a.m. | —9.00 a.m. | —10.00 a.m. | —11.00 a.m. | —12.00 m. | —1.00 p.m. | —2.00 p.m. | —3.00 p.m. | Total |
| 7.00 a.m. | Panicle I 12.45 p.m. | | | | | | 5 | 5 | 0 | 10 |
| | „ II 12.43 p.m. | | | | | | 2 | 7 | 1 | 10 |
| 8.00 a.m. | Panicle I 12.40 p.m. | | | | | | 2 | 3 | 0 | 5 |
| | „ II 8.12 a.m. | | 5 | 2 | 0 | 0 | 6 | 6 | 0 | 19 |
| 9.00 a.m. | Panicle I 9.07 a.m. | | | 4 | 0 | 3 | 5 | 5 | 0 | 17 |
| | „ II 9.05 a.m. | | | 10 | 1 | 0 | 1 | 7 | 0 | 19 |
| 10.00 a.m. | Panicle I 10.05 a.m. | | | | 24 | 0 | 0 | 0 | 0 | 24 |
| | „ II 10.05 a.m. | | | | 5 | 0 | 1 | 0 | 0 | 6 |
| Control (Outside) | Panicle I 11.45 a.m. | | | | | 2 | 4 | 4 | 1 | 11 |
| | „ II 11.42 a.m. | | | | | 1 | 7 | 3 | 2 | 13 |
| Control (Inside) | Panicle I 12.50 p.m. | | | | | | 1 | 12 | 4 | 17 |
| | „ II 1.18 p.m. | | | | | | | 8 | 3 | 11 |

TABLE 1.

(Continued)

Experiment IX.

(June 14, 1936. Weather: fine Variety: Asahi.)

| Time of transference of plants from outside to inside the house | Time when blooming begins | Number of blooming flowers in the given time | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | —7.00 a.m. | —8.00 a.m. | —9.00 a.m. | —10.00 a.m. | —11.00 a.m. | —12.00 m. | —1.00 p.m. | —2.00 p.m. | —3.00 p.m. | Total |
| 6.00 a.m. | Panicle I 12.16 p.m. | | | | | | 7 | 8 | 1 | | 16 |
| | " II 7.35 a.m. | 1 | 0 | 0 | 0 | 0 | 19 | 5 | 0 | | 25 |
| 7.00 a.m. | Panicle I 8.45 a.m. | | 1 | 1 | 0 | 0 | 10 | 0 | 0 | | 12 |
| | " II 8.02 a.m. | | 1 | 0 | 0 | 2 | 13 | 2 | 0 | | 18 |
| 8.00 a.m. | Panicle I 8.14 a.m. | | 3 | 1 | 0 | 2 | 9 | 1 | 0 | | 16 |
| | " II 8.12 a.m. | | 1 | 1 | 0 | 0 | 14 | 5 | 5 | | 26 |
| 9.00 a.m. | Panicle I 9.05 a.m. | | | 10 | 1 | 0 | 4 | 2 | 0 | | 17 |
| | " II 9.06 a.m. | | | 9 | 5 | 0 | 3 | 4 | 0 | | 21 |
| Control (Outside) | Panicle I 9.19 a.m. | | | 2 | 4 | 16 | 2 | 0 | 0 | | 24 |
| | " II 10.34 a.m. | | | | 2 | 18 | 2 | 0 | 0 | | 22 |
| Control (Inside) | Panicle I 11.50 a.m. | | | | | 1 | 9 | 1 | 0 | | 11 |
| | " II 11.50 a.m. | | | | | 2 | 13 | 1 | 0 | | 16 |

TABLE 1.
(Continued)
Experiment X.
(June 15, 1936. Weather: fine. Variety: Taino No. 22.)

| Time of transference of plants from outside to inside the house | Time when blooming begins | Number of blooming flowers in the given tim. | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | —7.00 a.m. | —8.00 a.m. | —9.00 a.m. | —10.00 a.m. | —11.00 a.m. | —12.00 m. | —1.00 p.m. | —2.00 p.m. | —3.00 p.m. | Total |
| 6.00 a.m. | Panicle I 11.41 a.m. | | | | | | 7 | 3 | 8 | 0 | 18 |
| | " II 11.41 a.m. | | | | | | 3 | 4 | 3 | 3 | 13 |
| 7.00 a.m. | Panicle I 11.39 a.m. | | | | | | 2 | 3 | 5 | 1 | 11 |
| | " II 7.16 a.m. | 1 | 0 | 0 | 0 | 1 | 1 | 4 | 2 | | 9 |
| 8.00 a.m. | Panicle I 8.05 a.m. | | | 4 | 0 | 1 | 2 | 1 | 2 | 1 | 11 |
| | " II 8.05 a.m. | | | 5 | 2 | 1 | 2 | 1 | 0 | 0 | 11 |
| 9.00 a.m. | Panicle I 9.04 a.m. | | | | 20 | 1 | 1 | 0 | 0 | 0 | 22 |
| | " II 9.04 a.m. | | | | 12 | 2 | 1 | 0 | 0 | 0 | 15 |
| 10.00 a.m. | Panicle I 10.03 a.m. | | | | | 23 | 0 | 0 | 0 | 0 | 23 |
| | " II 10.02 a.m. | | | | | 21 | 0 | 0 | 0 | 0 | 21 |
| Control (Outside) | Panicle I 10.29 a.m. | | | | | 6 | 14 | 7 | 0 | 0 | 27 |
| | " II 10.35 a.m. | | | | | 8 | 5 | 8 | 0 | 0 | 21 |
| Control (Inside) | Panicle I 12.47 p.m. | | | | | | | 4 | 8 | 5 | 17 |
| | " II 1.42 p.m. | | | | | | | | 4 | 2 | 6 |

TABLE 1.

(Continued)

Experiment XI.

(June 16, 1936. Weather: fine. Variety: Taino No. 22.)

| Time of transference of plants from outside to inside the house | Time when blooming begins | Number of blooming flowers in the given tin | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | — 7.00 a.m. | — 8.00 a.m. | — 9.00 a.m. | — 10.00 a.m. | — 11.00 a.m. | — 12.00 m. | — 1.00 p.m. | — 2.00 p.m. | — 3.00 p.m. | Total |
| 6.00 a.m. | Panicle I 10.36 a.m. | | | | | 1 | 14 | 10 | 3 | 0 | 28 |
| | " II 8.28 a.m. | | | 1 | 0 | 0 | 14 | 11 | 3 | 0 | 29 |
| 7.00 a.m. | Panicle I 7.10 a.m. | | 19 | 1 | 0 | 1 | 0 | 2 | 0 | 0 | 23 |
| | " II 7.08 a.m. | | 17 | 1 | 1 | 0 | 0 | 1 | 0 | 0 | 20 |
| 8.00 a.m. | Panicle I 8.04 a.m. | | | 15 | 0 | 0 | 0 | 1 | 0 | 0 | 16 |
| | " II 8.05 a.m. | | | 15 | 1 | 0 | 0 | 3 | 0 | 0 | 19 |
| 9.00 a.m. | Panicle I 9.04 a.m. | | | | 21 | 1 | 2 | 2 | 0 | 0 | 26 |
| | " II 9.04 a.m. | | | | 17 | 0 | 3 | 5 | 0 | 0 | 25 |
| Control (Outside) | Panicle I 9.10 a.m. | | | | 1 | 7 | 12 | 1 | 0 | 0 | 21 |
| | " II 10.35 a.m. | | | | | 4 | 21 | 4 | 1 | 0 | 30 |
| Control (Inside) | Panicle I 11.45 a.m. | | | | | | 22 | 5 | 0 | 0 | 27 |
| | " II 11.46 a.m. | | | | | | 16 | 6 | 0 | 0 | 22 |

blooming is usually delayed in Experiments XIV–XVIII (cf. Table 5) as compared with that in Experiments I–XI (Table 1), in the former case the experiments having been made from September to October while in the latter from May to June. It seems probable that the above mentioned fact may be caused by the seasonal differences of the experiments carried out.

The length of time between transference and the beginning of blooming is not always definite, but it is mostly from 3 to 10 minutes. Generally speaking it seems that the later the panicle is transferred, the more quickly it blooms, the most typical case being shown in Experiment V where the flowers began to open after 12, 9.5, 5 and 3.5 minutes respectively (average for 2 panicles) following the transference of each panicle at 6, 7, 8 and 9 a.m.

In the early transferred plants, the blooming process which has been hastened by the transference does not continue for long, the remaining flowers suspending the opening for some time until ordinary blooming period, and occurring again, thus presenting the "second blooming." The time of the second blooming comes a little later than that in the outside control plot and is practically the same as that of the inside control plot. In other words the blooming is hastened in some flowers by the transference and after a while the second blooming occurs again at the ordinary blooming time.

When the transference is made so early, the opening of only a few flowers is hastened and many flowers remain until the second blooming; the later the panicles are transferred, the greater the number of flowers that bloom early; on the contrary, it is difficult to find a clue indicating whether the blooming was hastened or not, if the transference was exceedingly late, e.g., at 10 a.m. In that case the blooming occurs only immediately after the transference and almost of all the flowers open within about one hour.

Adding up the number of blooming flowers shown in Table 1, the author has obtained Table 2 in which the percentage of the number of blooming flowers in the given time compared with the total number of them in each case of transferring is shown. The same is shown in Figs. 1*a*–1*f* in curve in which the general tendency above mentioned is clearly seen.

TABLE 2.

Percentage of blooming flowers in the given time.

| Time of transference of plants from outside to inside the house | Percentage in the given time | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | –7.00 a.m. | 8.00 a.m. | 9.00 a.m. | 10.00 a.m. | 11.00 a.m. | 12.00 m. | 1.00 p.m. | 2.00 p.m. | 3.00 p.m. | Total |
| 6.00 a.m. | 3.2 | 1.1 | 1.4 | 0.7 | 0.7 | 14.3 | 49.6 | 24.3 | 4.6 | 100 |
| 7.00 a.m. | | 22.4 | 4.0 | 3.5 | 1.4 | 9.8 | 36.9 | 14.7 | 7.2 | 100 |
| 8.00 a.m. | | | 50.6 | 5.9 | 2.8 | 6.1 | 22.1 | 9.6 | 2.8 | 100 |
| 9.00 a.m. | | | | 66.7 | 5.2 | 9.1 | 11.0 | 7.9 | 0.2 | 100 |
| 10.00 a.m. | | | | | 96.8 | 1.4 | 0.9 | 0.9 | 0.0 | 100 |
| Control (Outside) | | | | 2.0 | 24.3 | 55.9 | 12.4 | 4.7 | 0.6 | 100 |
| Control (Inside) | | | | | 0.9 | 29.1 | 32.3 | 25.1 | 12.6 | 100 |

Fig. 1. *a*.

Blooming transferred at 6 a.m.

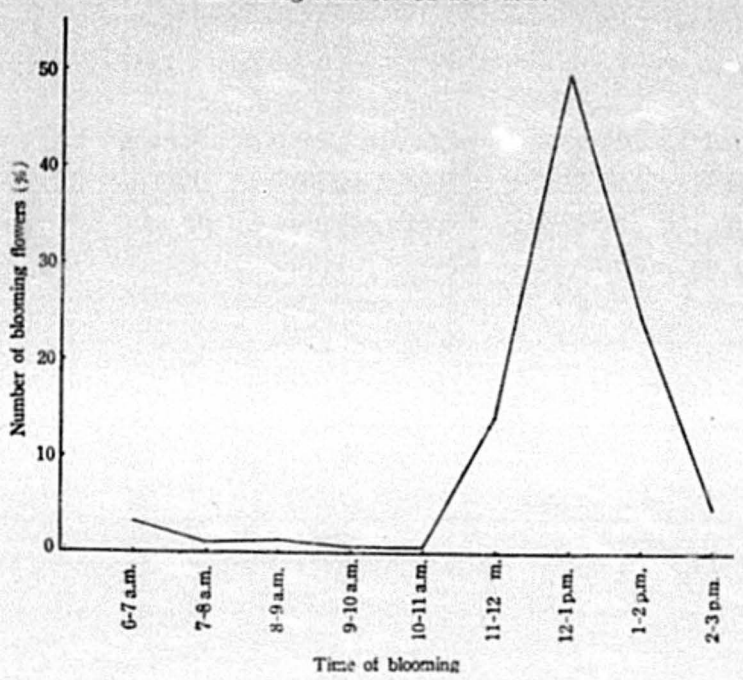


Fig. 1. *b.*

Blooming transferred at 7 a.m.

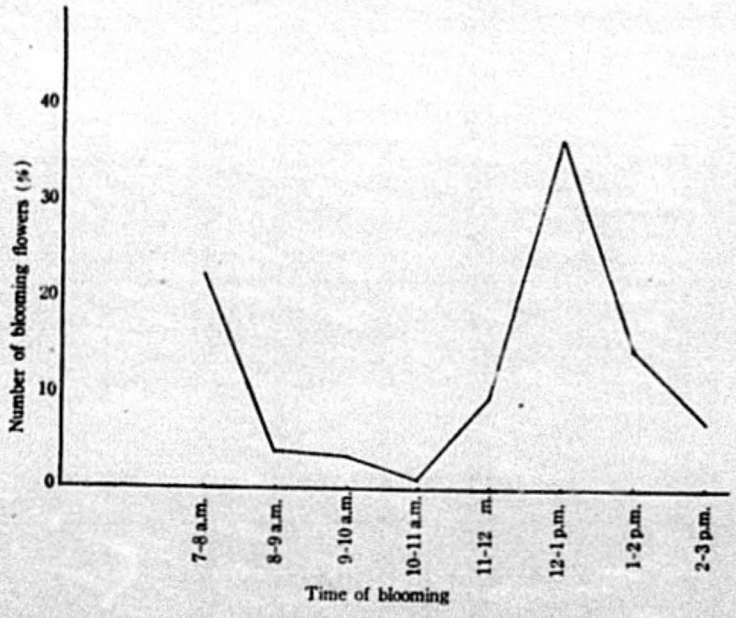
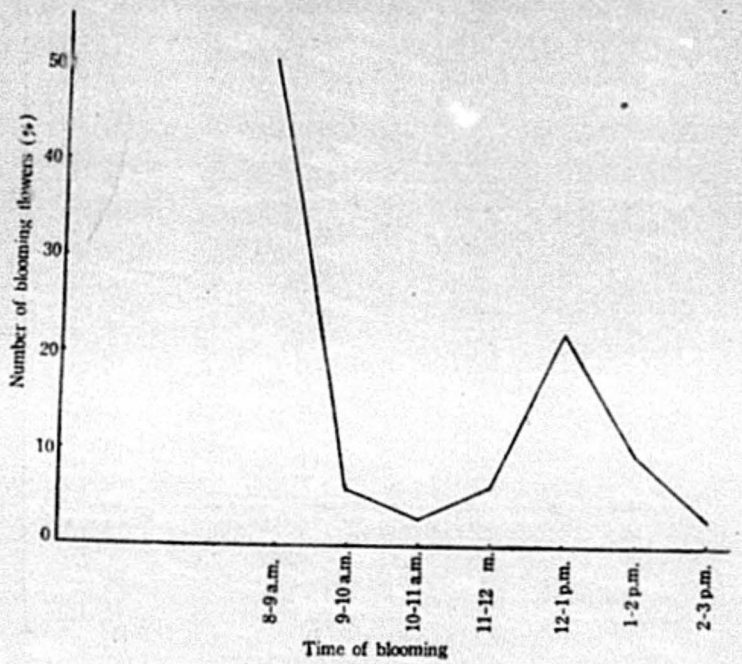



Fig. 1. *c.*

Blooming transferred at 8 a.m.



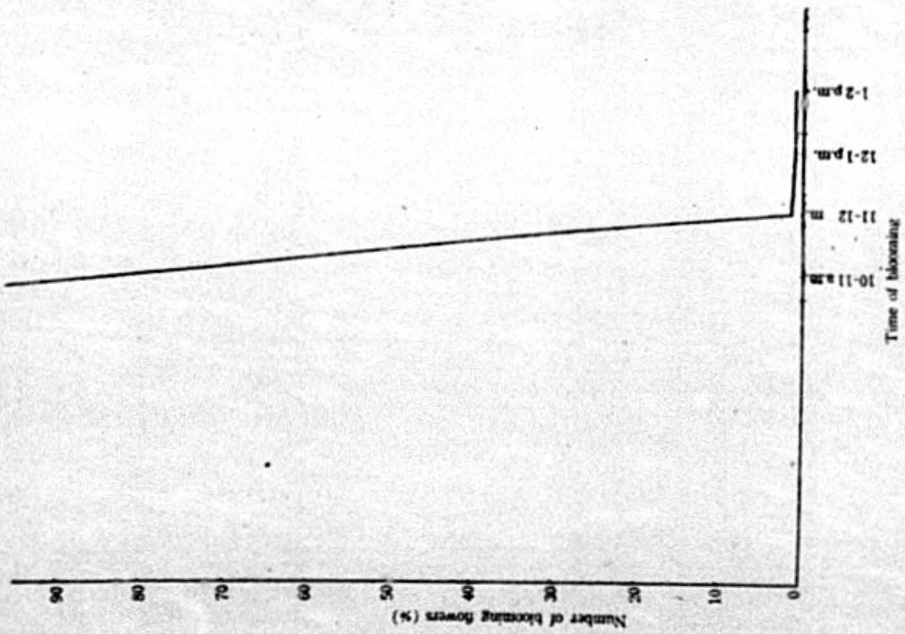



Fig. 1, *c*.
Blooming transferred at 10 a.m.

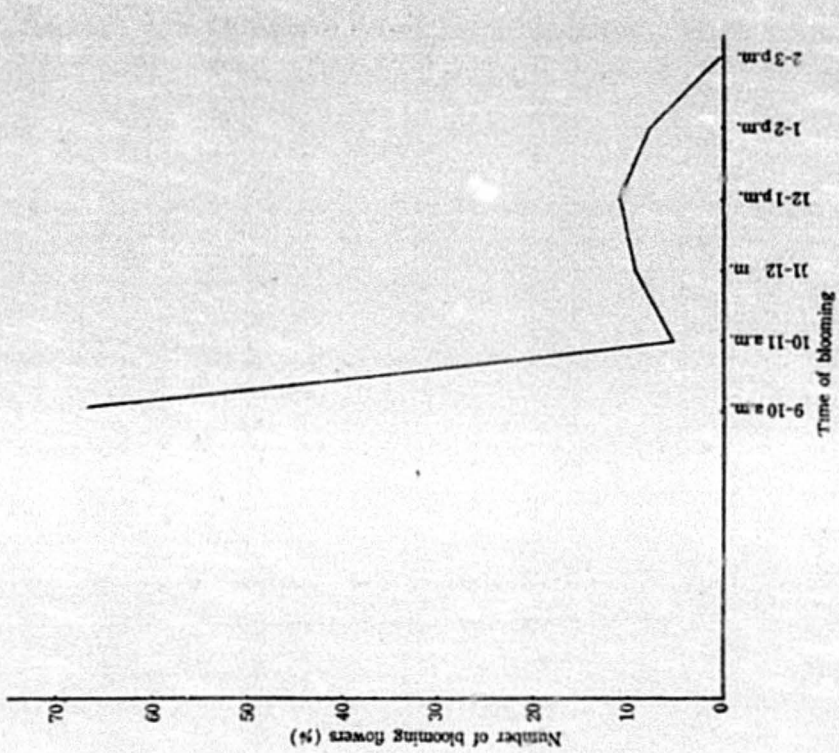
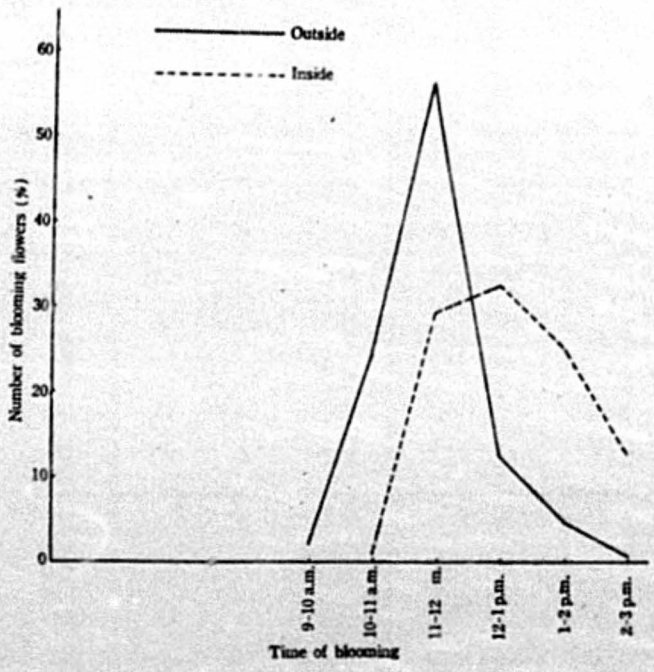



Fig. 1. *d*.
Blooming transferred at 9 a.m.

Fig. 1. *f.*

Blooming in the control plot.




### (3) Considerations on the mechanism of hastening by means of transference

#### *a) Relation between the temperature and the blooming*

It is often said that the blooming of rice flowers is closely related to the temperature of the day; and thus at first the author thought that the hastening of blooming by transference of the rice plant from the outside to the inside may be due to the change of temperature between the outside and the inside. In the above mentioned experiments the author has measured the temperatures both outside and inside the house at the time of transference. The results are given in Table 3.

TABLE 3.

Temperatures outside and inside the house at the time of transference in Experiments I–XI. (C.)

| Time of transference of plants from outside to inside the house | Temp. outside | Temp. inside | Difference | Temp. outside | Temp. inside | Difference | Temp. outside | Temp. inside | Difference |
|---|---|---|---|---|---|---|---|---|---|
| | Experiment I | | | Experiment II | | | Experiment III | | |
| 7.00 a.m. | 26.1° | 26.8° | 0.7° | 23.0° | 24.6° | 1.6° | 24.8° | 25.0° | 0.2° |
| 7.30 a.m. | 27.0 | 27.5 | 0.5 | 24.5 | 24.9 | 0.4 | — | — | — |
| 8.00 a.m. | 27.9 | 27.9 | 0.0 | 24.5 | 25.0 | 0.5 | 26.2 | 25.3 | −0.9 |
| 8.30 a.m. | 29.0 | 28.2 | −0.8 | 24.8 | 25.0 | 0.2 | — | — | — |
| 9.00 a.m. | 29.6 | 28.6 | −1.0 | 24.8 | 25.2 | 0.4 | 28.0 | 26.0 | −2.0 |
| 9.30 a.m. | 30.2 | 29.0 | −1.2 | 25.0 | 25.3 | 0.3 | — | — | — |
| 10.00 a.m. | 30.8 | 29.1 | −1.7 | 24.7 | 25.4 | 0.7 | — | — | — |
| | Experiment IV | | | Experiment V | | | Experiment VI | | |
| 6.00 a.m. | 23.7 | 25.2 | 1.5 | 24.5 | 26.0 | 1.5 | 25.0 | 25.0 | 0.0 |
| 7.00 a.m. | 24.2 | 25.2 | 1.0 | 25.0 | 25.3 | 0.3 | 25.0 | 25.2 | 0.2 |
| 8.00 a.m. | 26.5 | 26.0 | −0.5 | 26.5 | 26.0 | −0.5 | 25.5 | 25.2 | −0.3 |
| 9.00 a.m. | 27.8 | 26.0 | −1.8 | 29.0 | 26.7 | −2.3 | 25.2 | 26.0 | 0.8 |
| | Experiment VII | | | Experiment VIII | | | Experiment IX | | |
| 6.00 a.m. | 25.0 | 26.0 | 1.0 | — | — | — | 23.7 | 25.2 | 1.5 |
| 7.00 a.m. | 26.1 | 26.0 | −0.1 | 26.0 | 25.5 | −0.5 | 24.2 | 25.2 | 1.0 |
| 8.00 a.m. | 28.0 | 27.0 | −1.0 | 27.5 | 26.0 | −1.5 | 26.5 | 26.0 | −0.5 |
| 9.00 a.m. | 29.0 | 27.8 | −1.2 | 28.5 | 26.2 | −2.3 | 27.8 | 26.0 | −1.8 |
| 10.00 a.m. | 30.9 | 28.5 | −2.4 | 30.0 | 27.2 | −2.8 | — | — | — |
| | Experiment X | | | Experiment XI | | | | | |
| 6.00 a.m. | 24.5 | 26.0 | 1.5 | 24.0 | 26.2 | 2.2 | | | |
| 7.00 a.m. | 25.0 | 25.3 | 0.3 | 26.3 | 26.5 | 0.2 | | | |
| 8.00 a.m. | 26.5 | 26.0 | −0.5 | 27.3 | 27.0 | −0.3 | | | |
| 9.00 a.m. | 29.0 | 26.7 | −2.3 | 29.4 | 28.0 | −1.4 | | | |
| 10.00 a.m. | 29.2 | 27.0 | −2.2 | — | — | — | | | |

Note: Cases where inside temperature was lower, indicate by "—."

As shown in the preceding table, the temperature at 6 a.m. inside the house is generally 1°-2°C. higher than that outside; at 7 a.m. the difference between them decreases, and at 8 a.m., on the contrary, that of the outside becomes higher than that of the inside and the difference subsequently increases.*

Since there have been found no regular tendencies in the difference of temperature between the outside and the inside of the house during experiments, it is improbable that the occurrence of hastening of the blooming is due to the differences of temperature to which the plants are subjected. The hastening is able to occur even when the temperature does not differ at all between outside and inside (cf. Exp. I). On the contrary no hastening phenomena are found if the plants which have been kept inside during previous days are transferred from the inside to the outside whether a difference of temperature exists or not; the results found are given in Table 4.

* What is shown in Experiment II, is a peculiar case probably caused by the weather conditions of that particular day: the temperature of the inside was higher than that of the outside throughout the whole experiment.

TABLE 4.

Blooming of rice flowers transferred from the inside to the outside of the house.

Experiment XII.

(June 23, 1936. Weather: fine. Variety: Taichu No. 65.)

| Time of transference of plants from inside to outside the house | Temp. outside (C.) | Temp. inside (C.) | Difference (C.) | Time when blooming begins | Number of blooming flowers in the given time | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | -10.00 a.m. | 10.00-11.00 a.m. | 11.00-12.00 m. | 12.00—1.00 p.m. | 1.00—2.00 p.m. | 2.00—3.00 p.m. | Total |
| 6.00 a.m. | 26.0 | 27.9 | 1.9 | Panicle I 11.20 a.m. | | | 14 | 17 | 1 | 0 | 32 |
| | | | | „ II 11.23 a.m. | | | 16 | 18 | 6 | 2 | 42 |
| 7.00 a.m. | 26.0 | 27.0 | 1.0 | Panicle I 11.29 a.m. | | | 31 | 10 | 0 | 0 | 41 |
| | | | | „ II 10.56 a.m. | | 1 | 24 | 14 | 4 | 5 | 48 |
| 8.00 a.m. | 27.7 | 27.7 | 0.0 | Panicle I 11.20 a.m. | | | 5 | 29 | 8 | 0 | 42 |
| | | | | „ II 10.40 a.m. | | 1 | 29 | 22 | 1 | 0 | 53 |
| 9.00 a.m. | 29.0 | 28.5 | −0.5 | Panicle I 11.25 a.m. | | | 3 | 18 | 2 | 1 | 24 |
| | | | | „ II 10.55 a.m. | | 1 | 15 | 24 | 1 | 0 | 41 |
| 10.00 a.m. | 31.3 | 29.0 | −2.3 | Panicle I 11.25 a.m. | | | 7 | 46 | 0 | 1 | 54 |
| | | | | „ II 11.18 a.m. | | | 18 | 28 | 1 | 0 | 47 |
| Control (Outside) | | | | Panicle I 11.20 a.m. | | | 17 | 21 | 0 | 0 | 38 |
| | | | | „ II 11.15 a.m. | | | 32 | 12 | 2 | 4 | 50 |
| Control (Inside) | | | | Panicle I 11.05 a.m. | | | 17 | 13 | 12 | 3 | 45 |
| | | | | „ II 11.50 a.m. | | | 2 | 7 | 3 | 1 | 13 |

TABLE 4.

(Continued)

Experiment XIII.

(June 25, 1936. Weather: fine. Variety: Taichu No. 65.)

| Time of transference of plants from inside to outside the house | Temp. outside (C.) | Temp. inside (C.) | Difference (C.) | Time when blooming begins | Number of blooming flowers in the given time | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | —11.00 a.m. | —12.00 m. | — 1.00 p.m. | — 2.00 p.m. | — 3.00 p.m. | Total |
| 7.00 a.m. | 24.0 | 26.7 | 2.7 | Panicle I 11.40 a.m. | 25 | 3 | 2 | 0 | | 30 |
| | | | | „ II 11.40 a.m. | 23 | 9 | 1 | 0 | | 33 |
| 8.00 a.m. | 29.0 | 28.0 | −1.0 | Panicle I 11.40 a.m. | 24 | 0 | 1 | 0 | | 25 |
| | | | | „ II 11.40 a.m. | 29 | 5 | 0 | 0 | | 34 |
| 9.00 a.m. | 30.0 | 28.2 | −1.8 | Panicle I 11.40 a.m. | 33 | 9 | 2 | 0 | | 44 |
| | | | | „ II 11.40 a.m. | 20 | 8 | 6 | 0 | | 34 |
| Control (Outside) | | | | Panicle I 11.05 a.m. | 28 | 5 | 0 | 0 | | 33 |
| | | | | „ II 11.40 a.m. | 27 | 8 | 0 | 0 | | 35 |
| Control (Inside) | | | | Panicle I 11.05 a.m. | 13 | 7 | 6 | 0 | | 26 |
| | | | | „ II 12.45 p.m. | | 11 | 4 | 1 | | 16 |

### *b) Relation between the humidity and the blooming*

It becomes clear from what has been said in the previous section that the hastening of blooming caused by the transference of the panicle from the outside to the inside of the house is not due to the change of temperature. The humidity may be considered as one of the other factors. Some differences in humidity between the inside and the outside of the house may easily be supposed; the author then made some investigations of that problem, the results of which are shown in Table 5. The method used for these experiments is the same as for Experiments I–XI and the degrees of humidity are denoted by the figures of relative humidity.

TABLE 5.

Temperature and humidity outside and inside the house at the time of transference and blooming.

Experiment XIV.

(September 19, 1936. Weather: cloudy. Variety: Aikoku.)

| Time of transference of plants from outside to inside the house | Temp. outside (C.) | Temp. inside (C.) | Difference (C.) | Humidity outside (%) | Humidity inside (%) | Difference (%) | Time when blooming begins | Number of blooming flowers in the given time | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | —7.00 a.m. | —8.00 a.m. | —9.00 a.m. | —10.00 a.m. | —11.00 a.m. | —12.00 m. | —1.00 p.m. | —2.00 p.m. | —3.00 p.m. | Total |
| 6.00 a.m. | 24.0 | 25.0 | 1.0 | 79 | 77 | −2 | Panicle I 12.30 p.m. | | | | | | 1 | 7 | 8 | | 16 |
| 7.00 a.m. | 25.0 | 25.0 | 0.0 | 74 | 82 | 8 | Panicle I 12.24 p.m. | | | | | | 1 | 6 | 6 | | 13 |
| 8.00 a.m. | 26.0 | 25.8 | −0.2 | 73 | 77 | 4 | Panicle I 8.08 a.m. | | 8 | 2 | 1 | 0 | 5 | 2 | 2 | | 20 |
| 9.00 a.m. | 26.1 | 26.0 | −0.1 | 73 | 80 | 7 | Panicle I 9.12 a.m. | | | 1 | 1 | 1 | 3 | 4 | 1 | | 11 |
| 10.00 a.m. | 27.8 | 26.5 | −1.3 | 64 | 73 | 9 | Panicle I 10.08 a.m. | | | | 16 | 1 | 2 | 3 | 0 | | 22 |
| Control (Outside) | | | | | | | Panicle I 10.55 a.m. | | | | 1 | 6 | 7 | 0 | 0 | | 14 |
| Control (Inside) | | | | | | | Panicle I 12.25 p.m. | | | | | | 1 | 4 | 2 | | 7 |

TABLE 5.

(Continued)

Experiment XV.

(September 25, 1936. Weather: fine. Variety: Asahi.)

| Time of transference of plants from outside to inside the house | Temp. outside (C.) | Temp. inside (C.) | Difference (C.) | Humidity outside (%) | Humidity inside (%) | Difference (%) | Time when blooming begins | Number of blooming flowers in the given time | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | —7.00 a.m. | 8.00— a.m. | 9.00— a.m. | 10.00— a.m. | 11.00— a.m. | 12.00 m. | 1.00— p.m. | 2.00— p.m. | 3.00 p.m. | Total |
| 6.00 a.m. | 24.0 | 25.6 | 1.6 | 86 | 83 | −3 | Panicle I 12.47 p.m. | | | | | | 9 | 10 | 1 | | 20 |
| | | | | | | | „ II 12.28 p.m. | | | | | | 6 | 5 | 1 | | 12 |
| 7.00 a.m. | 24.5 | 25.5 | 1.0 | 89 | 87 | −2 | Panicle I 11.25 a.m. | | | | | | 3 | 25 | 8 | 3 | 39 |
| | | | | | | | „ II 11.42 a.m. | | | | | | 2 | 5 | 16 | 4 | 27 |
| 8.00 a.m. | 26.1 | 26.0 | −0.1 | 82 | 84 | 2 | Panicle I 11.45 a.m. | | | | | | 2 | 10 | 7 | 2 | 21 |
| | | | | | | | „ II 12.01 p.m. | | | | | | | 6 | 11 | 1 | 18 |
| 9.00 a.m. | 27.2 | 27.0 | −0.2 | 79 | 84 | 5 | Panicle I 9.09 a.m. | | | 6 | 1 | 9 | 2 | 2 | 1 | | 21 |
| | | | | | | | „ II 9.11 a.m. | | | 7 | 4 | 8 | 8 | 3 | 0 | | 30 |
| 10.00 a.m. | 27.5 | 27.3 | −0.2 | 78 | 84 | 6 | Panicle I 10.08 a.m. | | | | 14 | 4 | 0 | 1 | 2 | | 21 |
| | | | | | | | „ II 10.10 a.m. | | | | 14 | 5 | 1 | 3 | 0 | | 23 |
| Control (Outside) | | | | | | | Panicle I 11.56 a.m. | | | | | 1 | 7 | 0 | 0 | | 8 |
| | | | | | | | „ II 10.45 a.m. | | | | 1 | 1 | 5 | 1 | 0 | | 8 |
| Control (Inside) | | | | | | | Panicle I 12.35 p.m. | | | | | | 13 | 6 | 0 | | 19 |
| | | | | | | | „ II 12.49 p.m. | | | | | | 8 | 7 | 0 | | 15 |

TABLE 5.
(Continued)
Experiment XVI.
(September 26, 1936. Weather: cloudy. Variety: Shinriki.)

| Time of transference of plants from outside to inside the house | Temp. outside (C.) | Temp. inside (C.) | Difference (C.) | Humidity outside (%) | Humidity inside (%) | Difference (%) | Time when blooming begins | Number of blooming flowers in the give time | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | —7.00 a.m. | 8.00 a.m. | 9.00 a.m. | 10.00 a.m. | 11.00 a.m. | 12.00 m. | 1.00 p.m. | 2.00 p.m. | 3.00 p.m. | Total |
| 6.00 a.m. | 23.2 | 25.0 | 1.8 | 77 | 84 | 7 | Panicle I 12.35 p.m. | | | | | | | 8 | 2 | 9 | 19 |
| | | | | | | | " II 12.35 p.m. | | | | | | | 7 | 3 | 2 | 12 |
| 7.00 a.m. | 23.0 | 24.8 | 1.8 | 78 | 82 | 4 | Panicle I 11.42 a.m. | | | | | | 3 | 9 | 0 | 2 | 14 |
| | | | | | | | " II 11.42 a.m. | | | | | | 9 | 12 | 0 | 1 | 22 |
| 8.00 a.m. | 22.8 | 24.5 | 1.7 | 82 | 83 | 1 | Panicle I 11.45 a.m. | | | | | | 1 | 13 | 8 | 2 | 24 |
| | | | | | | | " II 11.40 a.m. | | | | | | 1 | 10 | 7 | 2 | 20 |
| 9.00 a.m. | 23.7 | 24.8 | 1.1 | 68 | 85 | 17 | Panicle I 9.18 a.m. | | | 5 | 3 | 1 | 6 | 2 | 3 | 20 | |
| | | | | | | | " II 9.15 a.m. | | | 8 | 3 | 0 | 1 | 0 | 0 | 12 | |
| 10.00 a.m. | 25.5 | 25.0 | −0.5 | 65 | 84 | 19 | Panicle I 10.12 a.m. | | | | 12 | 8 | 6 | 1 | 0 | 27 | |
| | | | | | | | " II 10.17 a.m. | | | | 3 | 0 | 9 | 0 | 2 | 14 | |
| 11.00 a.m. | 25.5 | 25.1 | −0.4 | 63 | 84 | 21 | Panicle I 11.09 a.m. | | | | | 15 | 4 | 1 | 0 | 20 | |
| | | | | | | | " II 11.09 a.m. | | | | | 12 | 3 | 1 | 0 | 16 | |
| Control (Outside) | | | | | | | Panicle I 11.45 a.m. | | | | | 2 | 8 | 0 | 4 | 14 | |
| | | | | | | | " II 11.45 a.m. | | | | | 3 | 16 | 0 | 2 | 21 | |
| Control (Inside) | | | | | | | Panicle I 12.30 p.m. | | | | | | 12 | 8 | 4 | 24 | |
| | | | | | | | " II 11.57 a.m. | | | | | 1 | 8 | 5 | 4 | 18 | |

TABLE 5.

(Continued)

Experiment XVII.

(October 9, 1936. Weather: rainy. Variety: Taino No. 16.)

| Time of transference of plants from outside to inside the house | Temp. outside (C.) | Temp. inside (C.) | Difference (C.) | Humidity outside (%) | Humidity inside (%) | Difference (%) | Time when blooming begins | Number of blooming flowers in the given time | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | —7.00 a.m. | 8.00—9.00 a.m. | 9.00—10.00 a.m. | 10.00—11.00 a.m. | 11.00—12.00 m. | 12.00—1.00 p.m. | 1.00—2.00 p.m. | 2.00—3.00 p.m. | 3.00—4.00 p.m. | Tota |
| 6.00 a.m. | 23.3 | 23.8 | 0.5 | 89 | 89 | 0 | Panicle I 11.50 a.m. | | | | | 2 | 1 | 3 | 3 | 0 | 9 |
| | | | | | | | " II 12.05 p.m. | | | | | | 2 | 3 | 5 | 2 | 12 |
| 7.00 a.m. | 23.4 | 23.8 | 0.4 | 89 | 89 | 0 | Panicle I 12.03 p.m. | | | | | | 2 | 3 | 12 | 0 | 17 |
| | | | | | | | " II 8.35 a.m. | 1 | 0 | 0 | 0 | | 1 | 4 | 9 | 0 | 15 |
| 8.00 a.m. | 23.5 | 24.0 | 0.5 | 89 | 89 | 0 | Panicle I 12.15 p.m. | | | | | | 3 | 3 | 3 | 2 | 11 |
| | | | | | | | " II 12.10 p.m. | | | | | | 6 | 5 | 5 | 3 | 19 |
| 9.00 a.m. | 23.5 | 24.1 | 0.6 | 90 | 90 | 0 | Panicle I 9.07 a.m. | | | 8 | 5 | 3 | 4 | 1 | 2 | 0 | 23 |
| | | | | | | | " II 9.18 a.m. | | | 2 | 2 | 3 | 2 | 6 | 4 | 0 | 19 |
| 10.00 a.m. | 23.5 | 24.1 | 0.6 | 90 | 91 | 1 | Panicle I 10.08 a.m. | | | | 14 | 2 | 1 | 1 | 4 | 0 | 22 |
| | | | | | | | " II 10.06 a.m. | | | | 5 | 6 | 6 | 0 | 0 | 0 | 17 |
| Control (Outside) | | | | | | | Panicle I 10.35 a.m. | | | | 1 | 1 | 3 | 5 | 4 | 3 | 15 |
| | | | | | | | " II 10.39 a.m. | | | | 5 | 1 | 3 | 1 | 1 | 3 | 14 |
| Control (Inside) | | | | | | | Panicle I 11.48 a.m. | | | | | 4 | 2 | 2 | 3 | 0 | 11 |
| | | | | | | | " II 11.48 a.m. | | | | | 2 | 3 | 1 | 4 | 0 | 10 |

TABLE 5.

(Continued)

Experiment XVIII.

(October 22, 1936. Weather: fine. Variety: Taichu No. 65.)

| Time of transference of plants from outside to inside the house | Temp. outside (C.) | Temp. inside (C.) | Difference (C.) | Humidity outside (%) | Humidity inside (%) | Difference (%) | Time when blooming begins | Number of blooming flowers in the given time | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | —7.00 a.m. | 8.00 a.m. | 9.00 a.m. | 10.00 a.m. | 11.00 a.m. | 12.00 m. | 1.00 p.m. | 2.00 p.m. | 3.0 p.m. | 4.00 p.m. | Total |
| 6.00 a.m. | 21.0 | 22.1 | 1.1 | 80 | 82 | 2 | Panicle I 1.45 p.m. | | | | | | | 1 | 4 | 3 | 8 |
| | | | | | | | " II 1.45 p.m. | | | | | | | 2 | 5 | 2 | 9 |
| 7.00 a.m. | 21.1 | 22.1 | 1.0 | 79 | 82 | 3 | Panicle I 12.45 p.m. | | | | | | 6 | 2 | 2 | 1 | 11 |
| | | | | | | | " II 1.53 p.m. | | | | | | | 2 | 4 | 0 | 6 |
| 8.00 a.m. | 22.7 | 23.1 | 0.4 | 72 | 82 | 10 | Panicle I 1.40 p.m. | | | | | | | 3 | 2 | 12 | 17 |
| | | | | | | | " II 1.28 p.m. | | | | | | | 5 | 3 | 2 | 10 |
| 9.00 a.m. | 23.8 | 23.8 | 0.0 | 73 | 79 | 6 | Panicle I 2.15 p.m. | | | | | | | | 5 | 4 | 9 |
| | | | | | | | " II 12.04 p.m. | | | | | | 1 | 2 | 3 | 2 | 8 |
| 10.00 a.m. | 25.0 | 24.5 | −0.5 | 68 | 74 | 6 | Panicle I 10.20 a.m. | | | | 4 | 3 | 0 | 1 | 1 | 0 | 9 |
| | | | | | | | " II 10.20 a.m. | | | | 3 | 3 | 2 | 0 | 2 | 4 | 14 |
| 11.00 a.m. | 25.4 | 24.8 | −0.6 | 64 | 74 | 10 | Panicle I 11.10 a.m. | | | | | 1 | 3 | 1 | 1 | 2 | 8 |
| | | | | | | | " II 11.15 a.m. | | | | | 2 | 2 | 1 | 0 | 1 | 6 |
| Control (Outside) | | | | | | | Panicle I 12.25 p.m. | | | | | | 2 | 1 | 10 | 0 | 13 |
| | | | | | | | " II 12.40 p.m. | | | | | | 3 | 0 | 6 | 6 | 15 |
| Control (Inside) | | | | | | | Panicle I 12.50 p.m. | | | | | | 2 | 8 | 2 | 3 | 15 |
| | | | | | | | " II 12.50 p.m. | | | | | | 2 | 6 | 5 | 0 | 13 |

TABLE 5.

(Continued)

Experiment XIX.

(May 27, 1937. Weather: fine. Variety: Aikoku.)

| Time of transference of plants from outside to inside the house | Temp. outside (C.) | Temp. inside (C.) | Difference (C.) | Humidity outside (%) | Humidity inside (%) | Difference (%) | Time when blooming begins | Number of blooming flowers in the given time | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | —7.00 a.m. | 8.00 a.m. | 9.00 a.m. | 10.00 a.m. | 11.00 a.m. | 12.00 m. | 1.00 p.m. | 2.00 p.m. | 3.00 p.m. | Total |
| 6.00 a.m. | 25.0 | 26.5 | 1.5 | 96 | 94 | −2 | Panicle I 11.55 a.m. | | | | | | 4 | 32 | 3 | 1 | 40 |
| | | | | | | | " II 10.50 a.m. | | | | | 2 | 9 | 30 | 0 | 0 | 41 |
| 7.00 a.m. | 25.8 | 27.2 | 1.4 | 93 | 95 | 2 | Panicle I 12.30 p.m. | | | | | | | 10 | 5 | 0 | 15 |
| | | | | | | | " II 7.40 a.m. | 1 | 0 | 0 | 0 | 0 | 25 | 2 | 1 | | 29 |
| 8.00 a.m. | 27.6 | 28.0 | 0.4 | 83 | 82 | −1 | Panicle I 8.07 a.m. | | 15 | 6 | 0 | 0 | 0 | 0 | 0 | | 21 |
| | | | | | | | " II 8.07 a.m. | | 18 | 3 | 0 | 0 | 0 | 0 | 0 | | 21 |
| 9.00 a.m. | 29.8 | 28.8 | −1.0 | 72 | 79 | 7 | Panicle I 9.04 a.m. | | | 29 | 1 | 1 | 2 | 1 | 0 | | 34 |
| | | | | | | | " II 9.05 a.m. | | | 26 | 3 | 0 | 1 | 2 | 1 | | 33 |
| 10.00 a.m. | 30.8 | 29.8 | −1.0 | 67 | 73 | 6 | Panicle I 10.03 a.m. | | | | 29 | 0 | 0 | 0 | 0 | | 29 |
| | | | | | | | " II 10.03 a.m. | | | | 25 | 1 | 0 | 2 | 0 | | 28 |
| Control (Outside) | | | | | | | Panicle I 10.01 a.m. | | | | 18 | 5 | 6 | 4 | 0 | | 33 |
| | | | | | | | " II 10.35 a.m. | | | | 8 | 14 | 7 | 0 | 0 | | 29 |
| Control (Inside) | | | | | | | Panicle I 11.40 a.m. | | | | | 1 | 25 | 6 | 1 | | 33 |
| | | | | | | | " II 12.30 p.m. | | | | | | 15 | 6 | 0 | | 21 |

TABLE 5.
(Continued)
Experiment XX.
(June 8, 1937. Weather: fine. Variety: Asahi.)

| Time of transference of plants from outside to inside the house | Temp. outside (C.) | Temp. inside (C.) | Difference (C.) | Humidity outside (%) | Humidity inside (%) | Difference (%) | Time when blooming begins | Number of blooming flowers in the given time | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | —7.00 a.m. | 8.00—9.00 a.m. | 9.00-10.00 a.m. | 10.00-11.00 a.m. | 11.00-12.00 m. | 12.00—1.00 p.m. | 1.00—2.00 p.m. | 2.00—3.00 p.m. | Total |
| 6.00 a.m. | 24.5 | 26.3 | 1.8 | 94 | 93 | −1 | Panicle I 11.05 a.m. | | | | | 17 | 1 | 2 | 0 | 20 |
| | | | | | | | " II 11.05 a.m. | | | | | 18 | 2 | 1 | 0 | 21 |
| 7.00 a.m. | 26.0 | 26.5 | 0.5 | 89 | 91 | 2 | Panicle I 7.30 a.m. | 2 | 2 | 3 | 6 | 2 | 3 | 1 | 0 | 19 |
| | | | | | | | " II 7.25 a.m. | 4 | 5 | 0 | 0 | 5 | 2 | 1 | 0 | 17 |
| 8.00 a.m. | 27.0 | 27.2 | 0.2 | 87 | 84 | −3 | Panicle I 8.05 a.m. | | 14 | 6 | 2 | 2 | 0 | 0 | 1 | 25 |
| | | | | | | | " II 8.06 a.m. | | 13 | 2 | 3 | 2 | 2 | 2 | 0 | 24 |
| 9.00 a.m. | 29.2 | 28.0 | −1.2 | 74 | 83 | 9 | Panicle I 9.05 a.m. | | | 25 | 2 | 2 | 0 | 0 | 0 | 29 |
| | | | | | | | " II 9.04 a.m. | | | 11 | 2 | 1 | 0 | 0 | 1 | 15 |
| Control (Outside) | | | | | | | Panicle I 9.45 a.m. | | | 1 | 13 | 4 | 1 | 0 | 0 | 19 |
| | | | | | | | " II 9.45 a.m. | | | 4 | 12 | 1 | 4 | 0 | 0 | 21 |
| Control (Inside) | | | | | | | Panicle I 10.25 a.m. | | | | 4 | 9 | 1 | 0 | 0 | 14 |
| | | | | | | | " II 9.40 a.m. | | | 1 | 0 | 14 | 2 | 0 | 0 | 17 |

In Table 5, there no definite relation is observable between the variation in humidity to which the flowers are subjected by the transference from the outside to the inside and the hastening of blooming. Just as in the case of temperature, the phenomenon of hastening of blooming is able to occur whether the humidity is different or not.

From the facts mentioned above, it is considered that the variation in relative humidity which the flower receives has no relation to the hastening of blooming brought about by means of the transference.

It may be additionally noted here that from the results of Experiments XIV–XVIII the initial time of blooming is later than that given in Table 1. As already mentioned this may be due to the difference of seasons. Taichu No. 65, for example, shows the earliest response to the treatment, while in the results given in Table 5 reverse is the case.

### c) *Relation between the change of light and the blooming*

As it has become clear from the author's experiments that no positive correlation between the change of temperature or humidity and the hastening of blooming by transference of rice plant from the outside to the inside of the house, can be found, the author takes the view that the change of light may serve as an external factor to account for the phenomenon. It is worth while noting here fact that the light inside the house was always weaker than that outside. Consequently the author tried several experiments in 1937 in order to find the relation, if any, between the hastening of blooming and the difference of light inside and outside.

As a preliminary experiment the author tried covering the rice plant with a dark box for 5 minutes outside of house and found that some of the flowers began to open before the natural blooming as shown in Table 6.

According to this experiment, in the three panicles which had been covered with a dark box at 7 a.m. for 5 minutes, 6 flowers bloomed immediately after covering; after 10 a.m. the remaining flowers began to bloom actively again resembling the case shown in Table 1. In the control plot they began to bloom about at 9 a.m. on that day, so it was observed that more than ten flowers had their blooming hastened by the treatment. In this experiment the light which the panicles received was completely intercepted; but if the cause of hastening the blooming is only the change of light introduced by the transference from the outside to the inside of the house, weakening of light, not complete interception, should be sufficient to bring about the hastening

TABLE 6.

Hastening phenomena in the blooming of rice flowers caused by interception of light.

Experiment XXI.

(July 10, 1937. Weather: fine. Variety: Taichu No. 65.)

| Time at which light was intercepted | | Number of blooming flowers in the given time | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | -7.05 a.m. | 7.35-8.05 a.m. | 8.05-8.35 a.m. | 8.35-9.05 a.m. | 9.05-9.35 a.m. | 9.35-10.05 a.m. | 10.05-11.05 a.m. | 11.05-12.05 p.m. | 12.05-1.05 p.m. | 1.05-2.05 p.m. | Total |
| 7.00 a.m. | Panicle I | 2 | 1 | 0 | 1 | 2 | 0 | 1 | 5 | 10 | 1 | 0 | 23 |
| | " II | 3 | 1 | 2 | 0 | 0 | 0 | 0 | 2 | 7 | 0 | 0 | 15 |
| | " III | 1 | 2 | 0 | 1 | 0 | 0 | 1 | 5 | 4 | 0 | 0 | 14 |
| Control | Panicle I | | | 1 | 0 | 2 | 2 | 1 | 5 | 6 | 0 | 0 | 17 |
| | " II | | | | | | | 7 | 9 | 4 | 0 | 0 | 20 |
| | " III | | | | | | | 1 | 7 | 2 | 0 | 0 | 10 |

Note: One flower bloomed between 7.35 and 8.05 a.m. in the control plot, but this occurs very seldom and should be regarded as caused by some special circumstance. The time of the blooming beginning in the control plot may practically be said to be about at 9 a.m.

phenomena. Starting from here the author tried detailed experiments in order to find out the relationship between the change of light and the hastening of blooming.

## MATERIAL AND METHOD

The variety of rice used for these experiments was Taichu No. 65, prepared in the same way as for Experiments I–XI. The experiments were carried out outside the house. A piece of black cloth about 2.5 meters square was spread over the panicle at about 45 cm above it. Under thus artificially weakened light, the author examined the states of blooming. The plants were divided into three plots, namely, (1) treatment was begun at 8 a.m., (2) at 9 a.m. and (3) the control plot. In Experiment XXII, 7 panicles, and in Experiment XXIII, 5 panicles were used.

## RESULTS OF THE EXPERIMENTS

The results of the experiments are shown in Table 7.

TABLE 7.

The hastening of blooming in rice flowers under artificially weakened light by spreading a black cloth over the plant.

Experiment XXII.

(October 6, 1937. Weather: fine. Variety: Taichu No. 65.)

| Time at which light was weakened | Time when blooming begins | Number of blooming flowers in the given time | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | —9.00 a.m. | 9.30 a.m. | 10.00 a.m. | 10.30 a.m. | 11.00 a.m. | 11.30 a.m. | 12.00 m. | 12.30 p.m. | 1.00 p.m. | 1.30 p.m. | 2.00 p.m. | Total |
| 8.00 a.m. | Panicle I 11.38 a.m. | | | | | | 24 | 10 | 2 | 0 | 1 | | 37 |
| | " II 11.38 a.m. | | | | | | 30 | 6 | 3 | 0 | 0 | | 39 |
| | " III 11.48 a.m. | | | | | | 11 | 16 | 2 | 0 | 0 | | 29 |
| | " IV 11.40 a.m. | | | | | | 9 | 20 | 4 | 0 | 0 | | 33 |
| | " V 11.36 a.m. | | | | | | 14 | 10 | 4 | 0 | 0 | | 28 |
| | " VI 11.46 a.m. | | | | | | 19 | 5 | 3 | 0 | 0 | | 27 |
| | " VII 11.34 a.m. | | | | | | 31 | 2 | 1 | 1 | 0 | | 35 |
| | Total | | | | | | 138 | 69 | 19 | 1 | 1 | | 228 |
| | % | | | | | | 60.5 | 30.3 | 8.3 | 0.4 | 0.4 | | 100 |
| 9.00 a.m. | Panicle I 9.07 a.m. | 2 | 2 | 0 | 2 | 1 | 1 | 14 | 5 | 1 | 0 | | 28 |
| | " II 9.09 a.m. | 11 | 2 | 2 | 1 | 0 | 3 | 8 | 1 | 0 | 2 | | 30 |
| | " III 9.07 a.m. | 10 | 3 | 6 | 1 | 2 | 2 | 1 | 3 | 2 | 1 | | 31 |
| | " IV 9.08 a.m. | 5 | 1 | 1 | 0 | 2 | 9 | 9 | 7 | 0 | 0 | | 34 |
| | " V 9.08 a.m. | 4 | 0 | 3 | 2 | 0 | 2 | 4 | 7 | 3 | 3 | | 28 |
| | " VI 9.07 a.m. | 5 | 0 | 2 | 0 | 0 | 2 | 2 | 4 | 1 | 1 | | 17 |
| | " VII 9.06 a.m. | 7 | 3 | 2 | 0 | 1 | 0 | 0 | 1 | 0 | 1 | | 15 |
| | Total | 44 | 11 | 16 | 6 | 6 | 19 | 38 | 28 | 7 | 8 | | 183 |
| | % | 24.0 | 6.0 | 8.7 | 3.3 | 3.3 | 10.4 | 20.8 | 15.3 | 3.8 | 4.4 | | 100 |
| Control | Panicle I 10.35 a.m. | | | | 1 | 8 | 12 | 14 | 3 | 2 | 0 | | 40 |
| | " II 11.43 a.m. | | | | | | 6 | 7 | 6 | 1 | 1 | | 21 |
| | " III 10.26 a.m. | | | 1 | 0 | 1 | 19 | 15 | 0 | 1 | 0 | | 37 |
| | " IV 10.25 a.m. | | | 1 | 4 | 7 | 8 | 10 | 6 | 0 | 0 | | 36 |
| | " V 11.36 a.m. | | | | | | 14 | 6 | 2 | 4 | 0 | | 26 |
| | " VI 11.51 a.m. | | | | | | 21 | 13 | 1 | 0 | 0 | | 35 |
| | " VII 11.50 a.m. | | | | | | 8 | 14 | 2 | 0 | 0 | | 24 |
| | Total | | | 2 | 5 | 16 | 88 | 79 | 20 | 8 | 1 | | 219 |
| | % | | | 0.9 | 2.3 | 7.3 | 40.2 | 36.1 | 9.1 | 3.7 | 0.5 | | 100 |

TABLE 7.
(Continued)
Experiment XXIII.
(October 8, 1937. Weather: fine. Variety: Taichu No. 65.)

| Time at which light was weakened | Time when blooming begins | Number of blooming flowers in the given time | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | —9.00 a.m. | 9.30—10.00 a.m. | 10.00—10.30 a.m. | 10.30—11.00 a.m. | 11.00—11.30 a.m. | 11.30—12.00 m. | 12.30—1.00 p.m. | 1.00—1.30 p.m. | 1.30—2.00 p.m. | Total |
| 8.00 a.m. | Panicle I 11.53 a.m. | | | | | | 1 | 41 | 2 | 0 | 0 | 44 |
| | " II 10.24 a.m. | | | 1 | 0 | 0 | 1 | 23 | 5 | 1 | 0 | 31 |
| | " III 11.37 a.m. | | | | | | 2 | 26 | 0 | 0 | 0 | 28 |
| | " IV 11.10 a.m. | | | | | 5 | 1 | 26 | 3 | 2 | 0 | 37 |
| | " V 11.40 a.m. | | | | | | 3 | 24 | 3 | 2 | 0 | 32 |
| | Total | | | 1 | 0 | 5 | 8 | 140 | 13 | 5 | 0 | 172 |
| | % | | | 0.6 | 0.0 | 2.9 | 4.7 | 81.4 | 7.6 | 2.9 | 0.0 | 100 |
| 9.00 a.m. | Panicle I 9.11 a.m. | 3 | 0 | 0 | 0 | 0 | 9 | 17 | 1 | 0 | 0 | 30 |
| | " II 11.53 a.m. | | | | | | 2 | 26 | 1 | 0 | 1 | 30 |
| | " III 9.10 a.m. | 6 | 2 | 3 | 0 | 0 | 1 | 14 | 1 | 2 | 0 | 29 |
| | " IV 9.11 a.m. | 1 | 0 | 0 | 0 | 0 | 1 | 30 | 3 | 0 | 0 | 35 |
| | " V 9.42 a.m. | | 1 | 0 | 0 | 0 | 0 | 25 | 1 | 4 | 0 | 31 |
| | Total | 10 | 3 | 3 | 0 | 0 | 13 | 112 | 7 | 6 | 1 | 155 |
| | % | 6.5 | 1.9 | 1.9 | 0.0 | 0.0 | 8.4 | 72.3 | 4.5 | 3.9 | 0.7 | 100 |
| Control | Panicle I 11.25 a.m. | | | | | 1 | 5 | 31 | 8 | 1 | 0 | 46 |
| | " II 11.40 a.m. | | | | | | 8 | 25 | 4 | 0 | 0 | 37 |
| | " III 11.20 a.m. | | | | | 3 | 4 | 12 | 3 | 1 | 0 | 23 |
| | " IV 11.43 a.m. | | | | | | 6 | 21 | 2 | 0 | 0 | 29 |
| | " V 12.10 p.m. | | | | | | | 29 | 0 | 0 | 1 | 30 |
| | Total | | | | | 4 | 23 | 118 | 17 | 2 | 1 | 165 |
| | % | | | | | 2.4 | 13.9 | 71.5 | 10.3 | 1.2 | 0.6 | 100 |

According to the above tables, while the treatment is scarcely effective in the plot where it was begun at 8 a.m., in the plot where the experiment was made at 9 a.m., many of the flowers bloomed early. As this experiment was made in the place where there were no direct rays, as already mentioned, no difference existed in temperature readings between the test-field (under the black cloth) and those of the field for control, though in the place where the sunshine falls directly, the temperature may rise very considerably under the black cloth. The momentary declination of the intensity of light may therefore be considered to be the direct cause of the phenomenon of the hastening of blooming brought about in this manner.

Does the phenomenon of hastening of blooming vary progressively according to the degrees of declinatian of light intensity? The answer to that is shown in Experiment XXIV which was carried out at the same time and in the same place as in Experiment XXIII. In this experiment not only the top part of the panicle was covered but also the black cloth hung down surrounding the whole plant, and only a very little visible light, was allowed to filter through from the bottom. The results are given in Table 8.

From Experiment XXIV, it is clearly shown that the blooming is markedly hastened in the plot where the treatment was carried out at 8 a.m. in spite of little effectiveness of Experiment XXIII at the same hour. It became clear from the preceding results that, if generally speaking, the greater the degree of variation in light intensity, the more effective the treatment.

From the fact that some flowers bloom within a few minutes of the treatment, it is presumed that the hastening of blooming brought about by the weakening of light is induced by a momentary agency and not by the long continued agencies of the weakened light. This has further been proved by another experiment carried out separately, the method of which was as follows: a rice plant was brought inside the house for one minute at 8.30 a.m. and then taken back to its original place. By this treatment more than 10 flowers per one panicle bloomed by 9 a.m., while those in the control began to bloom about 10 a.m. on that day.

As is clear from what has been already described, the direct cause of the hastening of blooming is a sudden decline of light intensity. This is a previously unknown characteristic peculiar to the blooming of rice flowers; and this is the reason why the phenomenon of hastening of blooming in rice flowers does not take place if the panicle is transferred from the inside to the outside of the house, but takes place only when the panicle is transferred from the outside to the inside of the house.

TABLE 8.

The hastening of blooming in rice flowers under artificially weakened light by spreading a black cloth over and around the plant.

Experiment XXIV.

(October 8, 1937. Weather: fine. Variety: Taichu No. 65.)

| Time at which light was weakened | Time when blooming begins | | Number of blooming flowers in the given time | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | —8.30 a.m. | —9.00 a.m. | —9.30 a.m. | —10.00 a.m. | —10.30 a.m. | —11.00 a.m. | —11.30 a.m. | —12.00 m. | —12.30 p.m. | —1.00 p.m. | —1.30 p.m. | —2.00 p.m. | Total |
| 8.00 a.m. | Panicle I | 8.08 a.m. | 11 | 1 | 3 | 1 | 1 | 1 | 0 | 0 | 9 | 0 | 0 | 1 | 28 |
| | " II | 8.10 a.m. | 4 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 27 | 1 | 0 | 0 | 33 |
| | " III | 8.10 a.m. | 5 | 1 | 4 | 5 | 0 | 3 | 0 | 0 | 18 | 0 | 0 | 0 | 36 |
| | " IV | 8.12 a.m. | 1 | 0 | 1 | 0 | 0 | 1 | 0 | 1 | 8 | 5 | 3 | 2 | 22 |
| | " V | 8.35 a.m. | | 1 | 1 | 1 | 1 | 1 | 2 | 3 | 13 | 1 | 1 | 2 | 27 |
| | Total | | 21 | 3 | 9 | 7 | 2 | 6 | 2 | 5 | 75 | 7 | 4 | 5 | 146 |
| | % | | 14.4 | 2.1 | 6.2 | 4.8 | 1.4 | 4.1 | 1.4 | 3.4 | 51.4 | 4.8 | 2.7 | 3.4 | 100 |
| 9.00 a.m. | Panicle I | 9.07 a.m. | | | 14 | 4 | 3 | 2 | 1 | 1 | 4 | 1 | 1 | 1 | 32 |
| | " II | 9.07 a.m. | | | 2 | 0 | 1 | 1 | 1 | 1 | 11 | 3 | 1 | 2 | 23 |
| | " III | 9.06 a.m. | | | 16 | 1 | 3 | 1 | 3 | 2 | 11 | 1 | 0 | 0 | 38 |
| | " IV | 9.12 a.m. | | | 2 | 0 | 0 | 0 | 1 | 1 | 8 | 0 | 4 | 1 | 17 |
| | " V | 9.10 a.m. | | | 5 | 0 | 1 | 0 | 0 | 1 | 20 | 0 | 5 | 1 | 33 |
| | Total | | | | 39 | 5 | 8 | 4 | 6 | 6 | 54 | 5 | 11 | 5 | 143 |
| | % | | | | 27.3 | 3.5 | 5.6 | 2.8 | 4.2 | 4.2 | 37.8 | 3.5 | 7.7 | 3.5 | 100 |
| Control | See control plot in Experiment XXIII. | | | | | | | | | | | | | | |

### *d) Relation between the environmental conditions preceding transference and the blooming*

Since it has been presumed that the phenomena of hastening of blooming in rice flowe vary owing to the environmental conditions to which the plants are subjected before transference, the author has carried out further experiments on the problem.

## MATERIAL AND METHOD

The variety used for the experiment was Taichu No. 65. The materials were prepared in the same way as for Experiments I–XI and were divided on the day preceding the experiment between the following two places which were in different environmental conditions.

A. Outside the house where the sun shines directly from the early morning.

B. Outside the house where there is no direct sunshine.

The author transferred these plants from both A and B at 8 and 9 a.m. into the same room and observed the state of the blooming. The observation was made on 4 panicles in each plot.

## RESULTS OF THE EXPERIMENT

The results of the experiment agreed with the author's expectations; that is, in the panicles which were exposed to the sunshine the blooming began quickly and a larger number of flowers bloomed early compared with those in the not exposed panicles, the results of which are shown in Table 9.

TABLE 9.

Blooming of rice flowers transferred from A and B places to the inside of the house.

Experiment XXV.

(October 7, 1937. Weather: fine. Variety: Taichu No. 65.)

| Time of transference of plants to inside the house | Conditions before transference | Time when blooming begins | Number of blooming flowers in the given ti | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | —8.30 a.m. | 8.30—9.00 a.m. | 9.00—9.30 a.m. | 9.30—10.00 a.m. | 10.00—10.30 a.m. | 10.30—11.00 a.m. | 11.00—11.30 a.m. | 11.30—12.00 m. | 12.00—12.30 p.m. | 12.30—1.00 p.m. | Total |
| 8.00 a.m. | A (Under direct sunshine) | Panicle I 8.07 a.m. | 17 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 3 | 0 | 22 |
| | | " II 8.07 a.m. | 32 | 1 | 1 | 2 | 0 | 0 | 1 | 1 | 1 | 0 | 39 |
| | | " III 8.08 a.m. | 16 | 2 | 3 | 0 | 0 | 0 | 0 | 0 | 4 | 0 | 25 |
| | | " IV 8.09 a.m. | 6 | 2 | 0 | 1 | 1 | 0 | 1 | 1 | 5 | 1 | 18 |
| | | Total | 71 | 6 | 4 | 4 | 1 | 0 | 2 | 2 | 13 | 1 | 104 |
| | | % | 68.3 | 5.8 | 3.8 | 3.8 | 1.0 | 0.0 | 1.9 | 1.9 | 12.5 | 1.0 | 100 |
| | B (No direct sunshine) | Panicle I 8.10 a.m. | 7 | 1 | 0 | 1 | 2 | 1 | 6 | 4 | 3 | 1 | 26 |
| | | " II 8.10 a.m. | 3 | 1 | 1 | 0 | 0 | 0 | 1 | 7 | 6 | 0 | 19 |
| | | " III 8.28 a.m. | 2 | 1 | 1 | 0 | 0 | 0 | 0 | 5 | 3 | 2 | 14 |
| | | " IV 8.11 a.m. | 4 | 0 | 0 | 1 | 0 | 0 | 13 | 8 | 5 | 0 | 31 |
| | | Total | 16 | 3 | 2 | 2 | 2 | 1 | 20 | 24 | 17 | 3 | 90 |
| | | % | 17.8 | 3.3 | 2.2 | 2.2 | 2.2 | 1.1 | 22.2 | 26.7 | 18.9 | 3.3 | 100 |
| 9.00 a.m. | A (Under direct sunshine) | Panicle I 9.05 a.m. | | | 32 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 33 |
| | | " II 9.05 a.m. | | | 23 | 2 | 0 | 0 | 0 | 1 | 0 | 0 | 26 |
| | | " III 9.05 a.m. | | | 16 | 2 | 1 | 0 | 1 | 0 | 2 | 0 | 22 |
| | | " IV 9.06 a.m. | | | 19 | 3 | 1 | 0 | 0 | 0 | 0 | 0 | 23 |
| | | Total | | | 90 | 7 | 3 | 0 | 1 | 1 | 2 | 0 | 104 |
| | | % | | | 86.5 | 6.7 | 2.9 | 0.0 | 1.0 | 1.0 | 1.9 | 0.0 | 100 |

| | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | B (No direct sunshine) | Panicle I | 9.13 a.m. | | 6 | 1 | 0 | 0 | 11 | 11 | 2 | 1 | 32 |
| | | " II | 9.08 a.m. | | 6 | 0 | 0 | 0 | 3 | 5 | 2 | 0 | 16 |
| | | " III | 9.06 a.m. | | 14 | 1 | 0 | 0 | 4 | 10 | 2 | 0 | 31 |
| | | " IV | 9.07 a.m. | | 10 | 1 | 2 | 1 | 2 | 2 | 2 | 2 | 22 |
| | | Total | | | 36 | 3 | 2 | 1 | 20 | 28 | 8 | 3 | 101 |
| | | % | | | 35.6 | 3.0 | 2.0 | 1.0 | 19.8 | 27.7 | 7.9 | 3.0 | 100 |
| Control | Outside of the house (Under direct sunshine) | Panicle I | 9.25 a.m. | | 1 | 4 | 9 | 12 | 4 | 0 | 1 | 0 | 31 |
| | | " II | 8.55 a.m. | 3 | 5 | 5 | 5 | 3 | 4 | 1 | 0 | 0 | 26 |
| | | " III | 9.45 a.m. | | | 2 | 11 | 5 | 3 | 0 | 0 | 0 | 21 |
| | | " IV | 8.58 a.m. | 1 | 1 | 6 | 3 | 5 | 4 | 1 | 0 | 0 | 21 |
| | | Total | | 4 | 7 | 17 | 28 | 25 | 15 | 2 | 1 | 0 | 99 |
| | | % | | 4.0 | 7.1 | 17.2 | 28.3 | 25.3 | 15.2 | 2.0 | 1.0 | 0.0 | 100 |
| | Outside of the house (No direct sunshine) | Panicle I | 10.25 a.m. | | | | 9 | 10 | 1 | 0 | 0 | 0 | 20 |
| | | " II | 10.55 a.m. | | | | | 6 | 11 | 2 | 3 | 2 | 24 |
| | | " III | 10.25 a.m. | | | | 1 | 8 | 20 | 2 | 0 | 0 | 31 |
| | | " IV | 10.50 a.m. | | | | | 13 | 11 | 2 | 1 | 0 | 27 |
| | | Total | | | | | 10 | 37 | 43 | 6 | 4 | 2 | 102 |
| | | % | | | | | 9.8 | 36.3 | 42.2 | 5.9 | 3.9 | 2.0 | 100 |
| | Inside of the house | Panicle I | 10.58 a.m. | | | | | 1 | 24 | 3 | 1 | 1 | 30 |
| | | " II | 10.20 a.m. | | | | 6 | 9 | 15 | 1 | 0 | 0 | 31 |
| | | " III | 10.32 a.m. | | | | | 3 | 14 | 5 | 0 | 3 | 25 |
| | | " IV | 10.40 a.m. | | | | | 1 | 13 | 3 | 0 | 0 | 17 |
| | | Total | | | | | 6 | 14 | 66 | 12 | 1 | 4 | 103 |
| | | % | | | | | 5.8 | 13.6 | 64.1 | 11.7 | 1.0 | 3.9 | 100 |

It is reasonable to think that the effect of this treatment upon the hastening of blooming is responsive in those flowers the internal conditions of which have been prepared to a certain extent. It is probable therefore that the sunshine (in this case it necessarily accompanies the agencies of temperature) had positive effects upon the preparation of the internal condition of the flowers. It may be explained in similar manner that the flowers are slow to respond to the treatment on a cloudy or a rainy day or on a day when the temperature is low.

### 2. *Blooming phenomena in rice flowers subjected to unusually high temperature*

It has previously been mentioned that the phenomenon of the hastening of the blooming in the case where the panicles are transferred from the outside to the inside of the house, is not ascribed to the difference of temperature between the inside and the outside. The author, however, came to the conclusion, following a subsequent experiment, that a certain change of temperature can also hasten the blooming.

#### MATERIAL AND METHOD

The variety used for this experiment was Taichu No. 65. As in the previous experiments, the plants were planted in pots which had been placed carefully inside the house on the day previous to that of observation. To raise the temperature surrounding the flower, beakers were warmed until the inside air temperature reached 35°, 40° and 50°C. respectively, and for 20 seconds they were very carefully placed over the panicles as not to touch them at all. Then the blooming states were examined. The material was arranged into 17 plots according to the times and the temperature, one panicle being used for the experiment in every plot.

#### RESULTS OF THE EXPERIMENT

Though the experiment showed no results in the 35°C. plot and a slight effect was seen in the 40°C. plot, the effect clearly appeared in the 50°C. one as shown in the following table.

TABLE 10.

The hastening of blooming in rice flowers caused by subjecting to high temperature.

Experiment XXVI.

(June 19, 1935)

| Time at which panicles were covered with warmed beaker | Room temp. (C.) | Treating temp. (C.) | Time when blooming begins | Number of blooming flowers in the given time | | | | | | | | | | | | | | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | -7.30 a.m. | 8.00 a.m. | 8.30 a.m. | 9.00 a.m. | 9.30 a.m. | 10.00 a.m. | 10.30 a.m. | 11.00 a.m. | 11.30 a.m. | 12.00 m. | 12.30 p.m. | 1.00 p.m. | 1.30 p.m. | 2.00 p.m. | |
| 7.00 a.m. | 26.0 | 35 | 11.40 a.m. | | | | | | | | | | 7 | 5 | 6 | 1 | 0 | 19 |
| | | 40 | 7.08 a.m. | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 8 | 6 | 3 | 2 | 0 | 21 |
| 7.30 a.m. | 26.3 | 35 | 10.45 a.m. | | | | | | | | 1 | 0 | 13 | 5 | 0 | 0 | 0 | 19 |
| | | 40 | 7.34 a.m. | | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 11 | 5 | 2 | 1 | 0 | 20 |
| | | 50 | 7.34 a.m. | | 5 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 2 | 7 | 2 | 1 | 19 |
| 8.00 a.m. | 26.6 | 35 | 11.45 a.m. | | | | | | | | | | 6 | 8 | 4 | 0 | 0 | 18 |
| | | 40 | 11.55 a.m. | | | | | | | | | | 9 | 4 | 4 | 0 | 0 | 17 |
| | | 50 | 8.05 a.m. | | | 7 | 0 | 1 | 0 | 0 | 0 | 0 | 2 | 4 | 4 | 1 | 0 | 19 |
| 8.30 a.m. | 26.9 | 35 | 11.50 a.m. | | | | | | | | | | 3 | 16 | 2 | 1 | 0 | 22 |
| | | 40 | 8.55 a.m.. | | | | 1 | 0 | 0 | 0 | 0 | 0 | 9 | 12 | 3 | 1 | 0 | 26 |
| | | 50 | 8.34 a.m. | | | | 7 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 3 | 0 | 0 | 11 |
| 9.00 a.m. | 27.4 | 35 | 11.40 a.m. | | | | | | | | | | 5 | 6 | 1 | 0 | 0 | 12 |
| | | 40 | 9.09 a.m. | | | | | 3 | 0 | 0 | 0 | 0 | 18 | 15 | 4 | 1 | 0 | 41 |
| | | 50 | 9.04 a.m. | | | | | 5 | 0 | 0 | 0 | 0 | 2 | 2 | 3 | 3 | 2 | 17 |
| 9.30 a.m. | 27.7 | 35 | 10.50 a.m. | | | | | | | | 1 | 0 | 17 | 3 | 1 | 1 | 1 | 24 |
| | | 40 | 9.33 a.m. | | | | | | 1 | 0 | 0 | 0 | 15 | 3 | 4 | 0 | 0 | 23 |
| | | 50 | 9.33 a.m. | | | | | | 5 | 1 | 0 | 1 | 1 | 1 | 4 | 1 | 0 | 14 |
| Control | | Panicle I | 10.35 a.m. | | | | | | | | 1 | 4 | 7 | 2 | 0 | 0 | 0 | 14 |
| | | " II | 11.57 a.m. | | | | | | | | | | 3 | 7 | 7 | 0 | 0 | 17 |

It may be seen from the above results that an unusually high temperature (above 40°C.) may possibly be a direct cause of hastening the blooming of rice flowers. According to the results of AKEMINE (1914) the most suitable temperature for blooming is 35°–40°C., and NOGUCHI (1927-a) found that the greatest number of flowers bloom at 30°C. In their experiments the panicles were continuously placed in a thermostat; while the author's experiment was carried out by subjecting the panicles to heat for only 20 seconds. In spite of the extremely short time, the hastening of blooming occurs, if the temperature is unusually high, which may possibly be regarded as a stimulative effect induced by high temperature.

### 3. *Blooming phenomena in rice flowers due to mechanical stimulation*

According to von TSCHERMAK, the blooming of rye can be hastened to a great extent by rubbing the panicles between the fingers or by shaking them; Körnicke also recognized the hastening of blooming in rye by mechanical stimulation (cited from FRUWIRTH 1923-a). The author, wishing to find out if the same phenomenon appears in rice, made some experiments in 1935 and 1937 and found that shaking of the panicles could not stimulate them sufficiently to hasten blooming, but that rubbing gave a stimulation sufficient to cause them to bloom quickly. The experiments and the results will be described in the following paragraphs.

#### (1) Relation between the rubbing of the panicle and the blooming

The materials used for this experiment were Taichu No. 65 cultivated in pots, similar to those in previous experiments, which were brought into the house on the day preceding the experiment and left there undisturbed. The panicle was rubbed with a piece of cloth from the bottom to the top. Taking into consideration the time when the rubbing was begun and the number of times of rubbing, the panicles were divided into 15 plots in each of which 2 panicles were used. The result is shown in Table 11. The number shown in that table is the total number of flowers that bloomed in 2 panicles.

TABLE 11.

The hastening of blooming in rice flowers caused by rubbing the panicle.

Experiment XXVII.

(June 16, 1935)

| Time at which panicles were rubbed | Number of times rubbed | Time when blooming begins | Number of blooming flowers in the given time | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | —7.30 a.m. | 8.00—8.30 a.m. | 8.30—9.00 a.m. | 9.00—9.30 a.m. | 9.30—10.00 a.m. | 10.00—12.00 m. | 12.00—2.00 p.m. | Total |
| 7.00 a.m. | 2 | 7.40 a.m. | | 15 | 2 | 1 | 0 | 0 | 5 | 3 | 26 |
| | 4 | 7.08 a.m. | 5 | 27 | 2 | 2 | 2 | 0 | 4 | 1 | 43 |
| | 6 | 7.11 a.m. | 6 | 10 | 11 | 2 | 2 | 1 | 2 | 3 | 37 |
| 7.30 a.m. | 2 | 7.37 a.m. | | 4 | 10 | 7 | 0 | 0 | 12 | 6 | 39 |
| | 4 | 7.36 a.m. | | 6 | 15 | 3 | 0 | 0 | 7 | 3 | 34 |
| | 6 | 7.37 a.m. | | 6 | 21 | 1 | 0 | 0 | 1 | 0 | 29 |
| 8.00 a.m. | 1 | 8.13 a.m. | | | 2 | 19 | 0 | 0 | 7 | 4 | 32 |
| | 2 | 8.06 a.m. | | | 11 | 19 | 0 | 0 | 2 | 1 | 33 |
| | 4 | 8.05 a.m. | | | 22 | 9 | 2 | 1 | 4 | 1 | 39 |
| 8.30 a.m. | 1 | 8.35 a.m. | | | | 12 | 14 | 2 | 2 | 0 | 30 |
| | 2 | 8.35 a.m. | | | | 22 | 16 | 0 | 4 | 0 | 42 |
| | 4 | 8.34 a.m. | | | | 22 | 20 | 0 | 2 | 1 | 45 |
| 9.00 a.m. | 1 | 9.05 a.m. | | | | | 11 | 21 | 5 | 1 | 38 |
| | 2 | 9.04 a.m. | | | | | 8 | 23 | 0 | 0 | 31 |
| | 4 | 9.04 a.m. | | | | | 25 | 15 | 1 | 0 | 41 |
| Control | | 10.10 a.m. | | | | | | | 34 | 7 | 41 |

TABLE 11.

(Continued)

Experiment XXVIII.

(June 24, 1935)

| Time at which panicles were rubbed | Number of times rubbed | Time when blooming begins | Number of blooming flowers in the given time | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | -6.30 a.m. | 7.00-7.30 a.m. | 7.30-8.00 a.m. | 8.00-9.00 a.m. | 9.00-10.00 a.m. | 10.00-11.00 a.m. | 11.00-12.00 m. | 12.00-1.00 p.m. | 1.00-2.00 p.m. | Total |
| 6.00 a.m. | 2 | 6.05 a.m. | 11 | 2 | 2 | 0 | 0 | 0 | 0 | 3 | 4 | 4 | 26 |
| | 6 | 6.05 a.m. | 10 | 11 | 3 | 1 | 0 | 0 | 0 | 0 | 0 | 2 | 27 |

Glancing through the results of Experiment XXVII, it is clearly seen that the panicles which were not rubbed, began to bloom at 10.10 a.m., while those which were rubbed, began to bloom as early as about 7 a.m. The state of blooming re mbles on the whole that in the case of weakening the light. Experiment XXVIII lacks the control plot, but it may be said that the blooming is obviously hastened by rubbing, since the blooming never takes place generally at 6 a.m. under natural environmental conditions. This experiment was carried out inside the house, but in the field too, it is not impossible to cause blooming by rubbing the panicles with the fingers provided the surrounding conditions are favourable.

### (2) Relation between the shaking of the panicle and the blooming

Using the same material as for Experiment XXVII, the author investigated the blooming phenomena after shaking the panicles from left to right by hand. One panicle was used for the experiment in each plot.

As is shown in Table 12, two flowers bloomed earlier in the plot where the panicle was shaken 20 times at 9.30 a.m. than in the control plot. However, it would probably be a hasty conclusion to say from the data described above, that the shaking has been effective in hastening blooming, so far as the author's experiment is concerned.

Subsequently an electric fan was used as another method of shaking, and the results obtained shown in Table 13. This experiment took place in the house and the panicles were fanned by an electric fan which was situated at 1.5 meters away. The variety used was Taichu No. 65 and 7 panicles of the two pots were used.

TABLE 12.

Blooming in rice flowers shaken by hand.

Experiment XXIX.

(June 20, 1935)

| Time at which panicles were shaken | Number of times shaken | Time when blooming begins | Number of blooming flowers in the given time | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | —9.30 a.m | —10.00 a.m. | —10.30 a.m. | —11.00 a.m. | —11.30 a.m. | —12.00 m. | —12.30 p.m. | —1.00 p.m. | —1.30 p.m. | —2.00 p.m. | —2.30 p.m. | Total |
| 7.30 a.m. | 10 | 11.25 a.m. | | | | | 1 | 8 | 2 | 6 | 1 | 0 | 0 | 18 |
| | 20 | 11.20 a.m. | | | | | 3 | 2 | 2 | 4 | 2 | 0 | 0 | 13 |
| 8.00 a.m. | 10 | 11.15 a.m. | | | | | 2 | 6 | 3 | 2 | 0 | 0 | 0 | 13 |
| | 20 | 11.35 a.m. | | | | | | 5 | 1 | 5 | 1 | 0 | 1 | 13 |
| 8.30 a.m. | 10 | 11.07 a.m. | | | | | 4 | 7 | 3 | 2 | 0 | 0 | 0 | 16 |
| | 20 | 10.40 a.m. | | | | 1 | 3 | 2 | 0 | 0 | 1 | 0 | 1 | 8 |
| 9.00 a.m. | 10 | 11.17 a.m. | | | | | 4 | 5 | 2 | 4 | 0 | 0 | 0 | 15 |
| | 20 | 10.40 a.m. | | | | 5 | 3 | 8 | 3 | 5 | 1 | 2 | 1 | 28 |
| 9.30 a.m. | 10 | 11.16 a.m. | | | | | 4 | 4 | 0 | 1 | 1 | 0 | 1 | 11 |
| | 20 | 9.55 a.m. | | 2 | 0 | 2 | 3 | 5 | 2 | 3 | 1 | 0 | 0 | 18 |
| Control | Panicle I | 10.35 a.m. | | | | 4 | 6 | 7 | 0 | 1 | 0 | 0 | 0 | 18 |
| | „ II | 11.25 a.m. | | | | | 3 | 4 | 4 | 4 | 0 | 0 | 0 | 15 |

TABLE 13.

Blooming in rice flowers shaken by the wind from an electric fan.
Experiment XXX.
(October 3, 1937)

| Time and duration of fanning | Time when blooming begins | Number of blooming flowers in the given time | | | | | |
|---|---|---|---|---|---|---|---|
| | | —10.00 a.m. | 10.00—11.00 a.m. | 11.00—12.00 m. | 1.00—5.00 p.m. | 5.00 p.m. | Total |
| From 7.00 a.m. to 1.00 p.m. | Panicle I 11.38 a.m. | | | 10 | 5 | 0 | 15 |
| | " II 11.42 a.m. | | | 9 | 5 | 1 | 15 |
| | " III 11.50 a.m. | | | 8 | 4 | 0 | 12 |
| | " IV 10.47 a.m. | | 1 | 10 | 14 | 0 | 25 |
| | " V 11.45 a.m. | | | 8 | 9 | 0 | 17 |
| | " VI 11.50 a.m. | | | 10 | 17 | 0 | 27 |
| | " VII 11.24 a.m. | | | 12 | 16 | 0 | 28 |
| | Total | | 1 | 67 | 70 | 1 | 139 |
| Control | Panicle I 12.20 p.m. | | | | 15 | 5 | 20 |
| | " II 12.30 p.m. | | | | 14 | 1 | 15 |
| | " III 11.50 a.m. | | | 7 | 17 | 2 | 26 |
| | " IV 12.15 p.m. | | | | 27 | 5 | 32 |
| | " V 11.55 a.m. | | | 2 | 20 | 6 | 28 |
| | " VI 12.20 p.m. | | | | 13 | 1 | 14 |
| | " VII 11.50 a.m. | | | 11 | 10 | 1 | 22 |
| | Total | | | 20 | 116 | 21 | 157 |

TABLE 13.
(Continued)
Experiment XXXI.
(October 5, 1937)

| Time and duration of fanning | Time when blooming begins | Number of blooming flowers in the given time | | | | | |
|---|---|---|---|---|---|---|---|
| | | —10.00 a.m. | 10.00—11.00 a.m. | 11.00—12.00 m. | 1.00—5.00 p.m. | 5.00 p.m. | Total |
| From 9.00 a.m. to 12 noon | Panicle I 10.18 a.m. | | 5 | 6 | 6 | 1 | 18 |
| | " II 10.12 a.m. | | 7 | 11 | 1 | 0 | 19 |
| | " III 10.13 a.m. | | 6 | 4 | 1 | 0 | 11 |
| | " IV 10.05 a.m. | | 8 | 21 | 4 | 1 | 34 |
| | " V 10.08 a.m. | | 1 | 12 | 1 | 0 | 14 |
| | " VI 9.37 a.m. | 1 | 4 | 12 | 2 | 0 | 19 |
| | " VII 10.08 a.m. | | 5 | 16 | 3 | 0 | 24 |
| | Total | 1 | 36 | 82 | 18 | 2 | 139 |
| Control | Panicle I 10.28 a.m. | | 4 | 17 | 4 | 0 | 25 |
| | " II 10.28 a.m. | | 1 | 1 | 2 | 0 | 4 |
| | " III 10.32 a.m. | | 3 | 10 | 0 | 0 | 13 |
| | " IV 9.38 a.m. | 2 | 7 | 12 | 6 | 1 | 28 |
| | " V 10.21 a.m. | | 1 | 8 | 7 | 2 | 18 |
| | " VI 10.09 a.m. | | 5 | 14 | 5 | 1 | 25 |
| | " VII 10.46 a.m. | | 4 | 2 | 3 | 0 | 9 |
| | Total | 2 | 25 | 64 | 27 | 4 | 122 |

As a result of this experiment, it was found that although shaking the panicles by fanning seems to hasten somewhat their blooming, its effect is not outstanding. The effect of shaking seems to be quite different from that caused by weakening the light, by raising the temperature or by rubbing.

Now according to the results seen in Experiments XXVII-XXXI, rubbing is useful as a mechanical stimulation inducing rice flowers to bloom but hardly any effect appears to be produced by shaking.

### 4. *Indehiscence of anthers in artificially hastened blooming flowers*

There can be observed a marked difference as regards the dehiscence of anthers between the transferred panicles and the control. In the former case where the panicles are transferred from the outside to the inside of the house the dehiscence of anthers does not occur in spite of the opening of glumes and the elongation of the filaments. It must be remarked that this is a noticeable phenomenon since the dehiscence in the rice plant generally occurs nearly at the same time or a little later than blooming.

According to SHARNGAPANI (1924), under natural conditions the dehiscence of the anther and pollination usually take place just before blooming. According to HECTOR (1913), ISO (1913), AKEMINE (1914), IKENO (1914), THOMPSTONE (1915), SUZUTA and TOMURA (1922) and ADAIR (1934), the dehiscence takes place just before or at the same times as the blooming, and according to TSUJIKAWA (1915), PARNELL and others (1917) and SANTOS (1933), it takes place following the opening of glumes as well as the elongation of the filaments. Besides these, KADAM and PATIL (1933) asserted that the anthers shed the pollen when the flower blooms. POGGENDORFF (1932) and SETHI and SAXENA (1930) have observed that the pollination may take place at any time, that is, before, during or after the blooming. BHIDE and BHALERAO (1927) said that in the flowers which bloom early in the morning, the dehiscence of anthers occurs about 5 minutes after the blooming, and if blooming occurs late and at that time the temperature has already risen, dehiscence and pollination take place at the same time as the blooming.

The dehiscence of the anthers is easily influenced by environmental conditions. According to ISO (1913), AKEMINE (1914) and NOGUCHI (1925), higher humidity is seen to retard the dehiscing of the anthers. It was further reported by AKEMINE (1914) and NOGUCHI (1927-a) that temperature, too low or

too high, may be a hindrance to the dehiscing of the anther. On the contrary, shaking of the panicles by the wind appears to be useful in dehiscing the anther as has already been reported by TSUJIKAWA (1915).

Observing blooming in natural environment, the author sometimes came across the fact that in flowers which bloomed early, dehiscing of the anthers did not occur at the same time as the blooming as reported by BHIDE (1925) and BHIDE and BHALERAO (1927). Most of the anthers dehisce, however, when the flowers bloom and shed a lot of pollen, and even before the blooming it is found, in some cases, that more or less pollen is seen on stigmas. KNUTH (1909) says that the anther dehisces after it hangs down over the glumes, but this is not seen ordinarily.

Thus it is important and necessary for the author to make clear the relation between the hastened blooming and the dehiscing of the anthers. The results of observations which were made in Experiments XXII–XXV are shown in Table 14.

TABLE 14.

Hastened blooming by artificial means in relation to the dehiscing of the anther.

| Experiment No. | Time at which hastening treatment was made | | Number of blooming flowers in the given time | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | —9.30 a.m. | 9.30—10.00 a.m. | 10.00—10.30 a.m. | 10.30—11.00 a.m. | 11.00—11.30 a.m. | 11.30—12.00 m. | 12.00—12.30 p.m. | 12.30—1.00 p.m. | 1.00—1.30 p.m. | 1.30—2.00 p.m. |
| XXII | 9.00 a.m. | Panicle I | **2** | **1 1** | **0** | **2** | **1** | **1** | **14** | **5** | **1** | **0** |
| | | „ II | **11** | **1 1** | **2** | **1** | **0** | **3** | **8** | **1** | **0** | **2** |
| | | „ III | **10** | **2 1** | **4 2** | **1** | **2** | **2** | **1** | **3** | **2** | **1** |
| | | „ IV | **5** | **1** | **1** | **0** | **2** | **9** | **9** | **7** | **0** | **0** |
| | | „ V | **4** | **0** | **1 2** | **1 1** | **0** | **2** | **4** | **7** | **3** | **3** |
| | | „ VI | **5** | **0** | **2** | **0** | **0** | **2** | **2** | **4** | **1** | **1** |
| | | „ VII | **7** | **3** | **1 1** | **0** | **1** | **0** | **0** | **1** | **0** | **1** |
| | | Total | **44** | **8 3** | **7 9** | **1 5** | **6** | **19** | **38** | **28** | **7** | **8** |
| | Control | Total (7 panicles) | | | **2** | **5** | **16** | **88** | **79** | **20** | **8** | **1** |

Note: Gothic figures refer to the number of flowers which bloomed with indehiscent anthers.

TABLE 14.

(Continued)

| Experiment No. | Time at which hastening treatment was made | | Number of blooming flowers in the given time | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | -9.30 a.m. | 10.00 a.m. | 10.30 a.m. | 11.00 a.m. | 11.30 a.m. | 12.00 m. | 12.30 p.m. | 1.00 p.m. | 1.30 p.m. | 2.00 p.m. |
| XXIII. | 9.00 a.m. | Panicle I | 3 | 0 | 0 | 0 | 0 | 9 | 17 | 1 | 0 | 0 |
| | | „ II | | | | | | 2 | 26 | 1 | 0 | 1 |
| | | „ III | 6 | 2 | 3 | 0 | 0 | 1 | 14 | 1 | 2 | 0 |
| | | „ IV | 1 | 0 | 0 | 0 | 0 | 1 | 30 | 3 | 0 | 0 |
| | | „ V | | 1 | 0 | 0 | 0 | 0 | 25 | 1 | 4 | 0 |
| | | Total | 10 | 3 | 3 | 0 | 0 | 13 | 112 | 7 | 6 | 1 |
| | Control | Total (5 panicles) | | | | | 4 | 23 | 118 | 17 | 2 | 1 |

TABLE 14.

(Continued)

| Experiment No. | Time at which hastening treatment was made | | Number of blooming flowers in the given time | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | —8.30 a.m. | 9.00 a.m. | 9.30 a.m. | 10.00 a.m. | 10.30 a.m. | 11.00 a.m. | 11.30 a.m. | 12.00 m. | 12.30 p.m. | 1.00 p.m. | 1.30 p.m. | 2.00 p.m. |
| XXIV | 8.00 a.m. | Panicle I | 11 | 1 | 3 | 1 | 1 | 1 | 0 | 0 | 9 | 0 | 0 | 1 |
| | | „ II | 4 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 27 | 1 | 0 | 0 |
| | | „ III | 5 | 1 | 4 | 5 | 0 | 3 | 0 | 0 | 18 | 0 | 0 | 0 |
| | | „ IV | 1 | 0 | 1 | 0 | 0 | 1 | 0 | 1 | 8 | 5 | 3 | 2 |
| | | „ V | | 1 | 1 | 1 | 1 | 1 | 2 | 3 | 13 | 1 | 1 | 2 |
| | | Total | 21 | 3 | 9 | 7 | 2 | 6 | 2 | 5 | 75 | 7 | 4 | 5 |
| | 9.00 a.m. | Panicle I | | | 14 | 4 | 3 | 2 | 1 | 1 | 4 | 1 | 1 | 1 |
| | | „ II | | | 2 | 0 | 1 | 1 | 1 | 1 | 11 | 3 | 1 | 2 |
| | | „ III | | | 16 | 1 | 2 1 | 1 | 3 | 2 | 11 | 1 | 0 | 0 |
| | | „ IV | | | 2 | 0 | 0 | 0 | 1 | 1 | 8 | 0 | 4 | 1 |
| | | „ V | | | 5 | 0 | 1 | 0 | 0 | 1 | 20 | 0 | 5 | 1 |
| | | Total | | | 39 | 5 | 5 3 | 4 | 6 | 6 | 54 | 5 | 11 | 5 |
| | Control | Total (5 panicles) | | | | | | | 4 | 23 | 118 | 17 | 2 | 1 |

TABLE 14.
(Continued)

| Experiment No. | Time at which hastening treatment was made | Conditions before transference | | Number of blooming flowers in the given time | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | 8.30 a.m. | 9.00 a.m. | 9.30 a.m. | 10.00 a.m. | 10.30 a.m. | 11.00 a.m. | 11.30 a.m. | 12.00 m. | 12.30 p.m. | 1.00 p.m. |
| XXV | 8.00 a.m. | A (Under direct sunshine) | Panicle I | 17 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 3 | 0 |
| | | | " II | 24 | 1 | 1 | 2 | 0 | 0 | 1 | 1 | 1 | 0 |
| | | | " III | 15 | 2 | 3 | 0 | 0 | 0 | 0 | 0 | 4 | 0 |
| | | | " IV | 5 | 2 | 0 | 1 | 1 | 0 | 1 | 1 | 5 | 1 |
| | | | Total | 61 | 6 | 4 | 2 | 2 | 1 | 0 | 2 | 2 | 13 | 1 |
| | | B (No direct sunshine) | Panicle I | 7 | 1 | 0 | 1 | 2 | 1 | 6 | 4 | 3 | 1 |
| | | | " II | 3 | 1 | 1 | 0 | 0 | 0 | 1 | 7 | 6 | 0 |
| | | | " III | 2 | 1 | 1 | 0 | 0 | 0 | 0 | 5 | 3 | 2 |
| | | | " IV | 4 | 0 | 0 | 1 | 0 | 0 | 13 | 8 | 5 | 0 |
| | | | Total | 16 | 3 | 2 | 2 | 2 | 1 | 20 | 24 | 17 | 3 |
| | 9.00 a.m. | A (Under direct sunshine) | Panicle I | | | 32 | 0 | 1 | 0 | 0 | 0 | 0 | 0 |
| | | | " II | | | 3 20 | 2 | 0 | 0 | 0 | 1 | 0 | 0 |
| | | | " III | | | 4 12 | 1 1 | 1 | 0 | 1 | 0 | 2 | 0 |
| | | | " IV | | | 11 8 | 3 | 1 | 0 | 0 | 0 | 0 | 0 |
| | | | Total | | | 18 72 | 1 6 | 3 | 0 | 1 | 1 | 2 | 0 |
| | | B (No direct sunshine) | Panicle I | | | 6 | 1 | 0 | 0 | 11 | 11 | 2 | 1 |
| | | | " II | | | 6 | 0 | 0 | 0 | 3 | 5 | 2 | 0 |
| | | | " III | | | 14 | 1 | 0 | 0 | 4 | 10 | 2 | 0 |
| | | | " IV | | | 10 | 1 | 1 1 | 1 | 2 | 2 | 2 | 2 |
| | | | Total | | | 36 | 3 | 1 1 | 1 | 20 | 28 | 8 | 3 |
| | Control | Outside of the house (Under direct sunshine) | Total (4 panicles) | | 4 | 7 | 17 | 28 | 25 | 15 | 2 | 1 | 0 |
| | | Outside of the house (No direct sunshine) | Total (4 panicles) | | | | | 10 | 37 | 43 | 6 | 4 | 2 |
| | | Inside of the house | Total (4 panicles) | | | | | 6 | 14 | 66 | 12 | 1 | 4 |

In the course of the observations made in Experiments XXII–XXIV, the author found that the anthers of the flowers which bloomed before 9.30 a.m. were dark yellow in colour, showing a vivid colour tone and were so hard that the shedding of pollen was prevented, while in those which bloomed later, the anthers were lighter in colour to almost white and assumed a colour tone which looked as if it had been dried up, and sometimes scattered pollen when touched with the forceps. In the case where the flowers bloomed after 11 a.m., the dehiscence of anthers occurred nearly at the same time as the blooming.

In Experiment XXV, however, in plot B (the situation of the materials before transference was the same as in Experiment XXII–XXIV) the state of indehiscence of the anthers resembled that mentioned above, but in plot A on which the sun shone directly from early in the morning the anther dehisced earlier. For example, in the panicles which were transferred into the house at 8 a.m., 71 flowers bloomed within 30 minutes out of which the anthers dehisced in 10 flowers. In other words, the external conditions before the treatment have an effect not only upon the hastening of blooming but also upon the degree of dehiscing of the anthers at the same time.

Generally speaking, with the same variety in the same environment, the earlier the treatment is made the more difficult is it for the anther to open, and the later it is carried out, the easier it is to dehisce. Consequently it seems to be reasonable that the self-fertilization seldom occurs in the flowers which bloom early in the morning by transference. In 1936, for 18 days in May and June, the author emasculated the anthers, soon after blooming, of the flowers which bloomed within an hour of transference from the outside to the inside of the house at various times between 7 and 10 a.m. (all the flowers which did not bloom in a given time were cut off), and the number of flowers in which the self-fertilization took place were studied. The panicles were divided into 3 groups; namely one which was transferred before 8 a.m., and two others transferred between 8 and 9 a.m. and after 9 a.m. respectively. The results obtained are as follows:

TABLE 15.

Relation between the time of transference and the self-fertilization of flowers blooming during the following hour.

| Time at which plants were transferred from outside to inside the house | Number of flowers studied | Number of self-fertilized flowers | Percentage of self-fertilized flowers |
|---|---|---|---|
| 7–8 a.m. | 150 | 0 | 0.0 |
| 8–9 a.m. | 164 | 12 | 7.3 |
| 9–10 a.m. | 183 | 81 | 44.3 |

Note: 17 varieties supplied.

According to Table 15, in the flowers that were transferred before 8 a.m. and bloomed within an hour, no one dehisced its anthers; but the later they were transferred, the larger the number of flowers with their anthers dehisced.

By these experiments it is possible to conclude that while the anthers dehisce immediately after blooming and scatter the pollen if the transference is carried out comparatively later, in the case of earlier transference, the anthers do not dehisce for a long time, until they have shot themselves out and hung over and, finally, faded. In these faded anthers the pollen grains can be found clinging together. Therefore very few among those flowers treated early, fructify themselves even if the anthers are unremoved. An example may be mentioned here of this, i.e.: in June 1935, the author hastened the blooming by covering the plants with a dark box at 8.30 a.m. for 10 minutes, then cut all the flowers that had not bloomed before 10 a.m. leaving all the flowers which bloomed (not emasculated). Out of 87 flowers in 4 panicles, only three bore mature grains.

Besides these states of indehiscence of the anthers, there are more or less considerable differences between the flowers that have bloomed naturally and those hastened, regarding the size of the lodicules, the angle of opening of the glumes and the length of the filaments. These will be found given in Chapter IV.

## III. EXPERIMENTAL STUDIES ON SOME ENVIRONMENTAL FACTORS AFFECTING THE NATURAL BLOOMING TIME OF RICE FLOWERS

It is recognized that rice flowers bloom at about a given time every day so long as the environmental conditions are favourable. Accordingly it is not difficult to suppose that the blooming is closely related to those environmental factors which are changeable periodically during the course of every day. The daily change which seems to be periodically most regular is possibly found in the light, the next being temperature and relative humidity. The author, in this chapter, will describe the experimental results obtained and add some considerations on the relation between the blooming time of the day and the environmental factors.

### 1. *Effect of light upon time of blooming*

Since the periodical most regular daily change of light is the alternation

of day and night, the author presumed that this change of light may have an important effect upon the periodicity of the blooming time for rice flowers. Although some reports have been published dealing with the relationship between the blooming of rice flowers and the light (AKEMINE 1914, NOGUCHI 1926, and NAKAO 1911), these are not sufficient to explain satisfactorily that problem. The author therefore carried out some experiments in 1937 to make clear the effect of light upon blooming.

## EXPERIMENT XXXII

The author proposes to find out what relation subsists between the alternation of day and night and blooming. For this experiment the following 4 plots were prepared.

Plot 1. Lighted continuously.

Plot 2. Darkened in the daytime and lighted at night. (Darkened from 6 a.m. to 6 p.m., lighted from 6 p.m. to 6 a.m.)

Plot 3. Lighted by day and darkened at night. (Lighted from 6 a.m. to 6 p.m., darkened from 6 p.m. to 6 a.m.)

Plot. 4. Control. (Under natural conditions.)

Except for the control plot the other three plots were prepared in the inside of the house which receives no light from the outside. For lighting purposes an electric lamp (100 w at about 1 meter's distance) was used. The treatment was begun on June 12th; the number of blooming flowers was counted every 4 hours for 5 days, that is, from 2 p.m. on June 16th to 2 p.m. on June 21st. The reason why the investigation was made 4 days after the treatment had been begun, was to avoid the complication of results due to the after effects of conditions preceding the treatment. The variety used for this experiment was Taichu No. 65, and in every plot 10 panicles of 4 plants were supplied. The results of the observations carried out on the eight panicles which showed similar development are shown in the following Tables 16–19. Though the temperature in the darkened room generally rises noticeably in summer and often produces an adverse effect upon the growth of the plant, the author has had the good fortune during this experiment to have rainy or cloudy days, the temperature of the room consequently was about 24°–29°C. (cf. Appendix Tables I and III) and therefore rather favourable to the experiments.

TABLE 16.

Blooming of rice in Plot 1.

(Lighted continuously.)

| Date and time when the number of blooming flowers was counted | Number of blooming flowers | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Panicles | | | | | | | | Total |
| | I | II | III | IV | V | VI | VII | VIII | |
| June 16th— 6 p.m. | 1 | 2 | | | 2 | 1 | | | 6 |
| 10 p.m. | | 2 | | | | | | | 2 |
| 17th— 2 a.m. | | 2 | | | | | | | 2 |
| 6 a.m. | 3 | | | | | | 1 | 1 | 5 |
| 10 a.m. | | 2 | | | 2 | 1 | | | 5 |
| 2 p.m. | 5 | 2 | 2 | 1 | 15 | 5 | | 1 | 31 |
| 6 p.m. | | | | | 7 | 2 | 1 | | 10 |
| 10 p.m. | 1 | | | 1 | 5 | 1 | | 3 | 11 |
| 18th— 2 a.m. | 2 | | 1 | | 3 | | | 6 | 12 |
| 6 a.m. | 1 | | | | 1 | | | 6 | 8 |
| 10 a.m. | 1 | 2 | | 1 | | 3 | 1 | | 8 |
| 2 p.m. | 1 | 5 | | 5 | 4 | 8 | | | 23 |
| 6 p.m. | | 2 | 2 | 4 | | 5 | 1 | 1 | 15 |
| 10 p.m. | | | 4 | 3 | | 5 | 3 | 2 | 17 |
| 19th— 2 a.m. | 1 | | 3 | | 2 | 1 | | 2 | 9 |
| 6 a.m. | 2 | 1 | | 1 | | 4 | | 2 | 10 |
| 10 a.m. | 3 | 1 | 2 | 1 | 1 | 1 | | 1 | 10 |
| 2 p.m. | | 3 | 1 | 3 | 2 | 3 | 4 | 1 | 17 |
| 6 p.m. | 2 | 1 | 2 | 1 | 1 | | 3 | 1 | 11 |
| 10 p.m. | 3 | 1 | 1 | 1 | | | 3 | | 9 |
| 20th— 2 a.m. | 2 | | 2 | 3 | | 1 | 2 | 1 | 11 |
| 6 a.m. | 4 | | 2 | 1 | | 3 | 2 | 1 | 13 |
| 10 a.m. | 5 | 2 | 1 | 1 | | 2 | 5 | 6 | 22 |
| 2 p.m. | 2 | 3 | 3 | 4 | | 5 | 3 | 1 | 21 |
| 6 p.m. | 1 | 2 | 2 | | 1 | 2 | 1 | 3 | 12 |
| 10 p.m. | | 1 | 5 | 2 | | 3 | 2 | | 13 |
| 21st— 2 a.m. | 3 | | 14 | 1 | | 1 | 2 | 1 | 22 |
| 6 a.m. | | | 16 | 1 | | 1 | 3 | | 21 |
| 10 a.m. | 3 | | 5 | 4 | | | | | 12 |
| 2 p.m. | 5 | | 4 | 3 | | 6 | | 1 | 19 |

TABLE 17.

Blooming of rice in Plot 2.

(Darkened in the daytime and lighted at night.)

| Date and time when the number of blooming flowers was counted | Number of blooming flowers | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Panicles | | | | | | | | Total |
| | I | II | III | IV | V | VI | VII | VIII | |
| June 16th— 6 p.m. | | | | 2 | 1 | 1 | 1 | 5 | 10 |
| 10 p.m. | | | | 11 | 2 | 6 | 10 | 16 | 45 |
| 17th— 2 a.m. | 1 | 3 | | 21 | 4 | 9 | 16 | 13 | 67 |
| 6 a.m. | | 3 | | | 1 | | 1 | 2 | 7 |
| 10 a.m. | | | | | | | | | 0 |
| 2 p.m. | | | | | | | | | 0 |
| 6 p.m. | | 2 | | 2 | | 1 | | 3 | 8 |
| 10 p.m. | | 2 | | 7 | 5 | 4 | | 2 | 20 |
| 18th— 2 a.m. | | | | 4 | 2 | 7 | 6 | 2 | 21 |
| 6 a.m. | | | | 6 | 4 | 2 | 8 | 2 | 22 |
| 10 a.m. | | | | | 2 | | 2 | 1 | 5 |
| 2 p.m. | | | | 2 | 3 | | | | 5 |
| 6 p.m. | | | | 2 | 6 | 1 | 2 | 2 | 13 |
| 10 p.m. | 2 | 15 | 5 | 23 | 12 | 18 | 22 | 7 | 104 |
| 19th— 2 a.m. | 11 | 12 | 6 | 11 | 11 | 6 | 18 | 10 | 85 |
| 6 a.m. | 5 | 1 | 3 | | | | | 2 | 12 |
| 10 a.m. | | | 3 | | 1 | | | | 4 |
| 2 p.m. | | | | | | | | | 0 |
| 6 p.m. | | | | | 1 | | | | 1 |
| 10 p.m. | 1 | 2 | 5 | | | 1 | 1 | 3 | 13 |
| 20th— 2 a.m. | | | 2 | 5 | 4 | | 1 | 1 | 13 |
| 6 a.m. | | | 1 | 3 | | | 1 | | 5 |
| 10 a.m. | | | | | | | | | 0 |
| 2 p.m. | | | | | | | | | 0 |
| 6 p.m. | 5 | 1 | | | | | | | 6 |
| 10 p.m. | 9 | 2 | 5 | | 1 | 1 | 4 | 2 | 24 |
| 21st— 2 a.m. | 10 | 3 | 2 | | 3 | 1 | 7 | | 26 |
| 6 a.m. | | | | | | | | | 0 |
| 10 a.m. | | | | | | | | | 0 |
| 2 p.m. | | | | | | | | | 0 |

TABLE 18.

Blooming of rice in Plot 3.

(Lighted in the daytime and darkened at night.)

| Date and time when the number of blooming flowers was counted | Number of blooming flowers | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Panicles | | | | | | | | Total |
| | I | II | III | IV | V | VI | VII | VIII | |
| June 16th— 6 p.m. | | | | | | | | | 0 |
| 10 p.m. | | | | | | | | | 0 |
| 17th— 2 a.m. | | | | | | | | | 0 |
| 6 a.m. | | | | | | | | | 0 |
| 10 a.m. | | | | | | | | | 0 |
| 2 p.m. | 10 | 19 | 19 | 11 | 4 | 2 | 6 | 5 | 76 |
| 6 p.m. | | | | | | | | | 0 |
| 10 p.m. | | | | | | | | | 0 |
| 18th— 2 a.m. | 1 | | | | | | | | 1 |
| 6 a.m. | | | | | | | | | 0 |
| 10 a.m. | 1 | | | 1 | | | | | 2 |
| 2 p.m. | 8 | 12 | 14 | 8 | 10 | 5 | 4 | 7 | 68 |
| 6 p.m. | | | | | | | | | 0 |
| 10 p.m. | | | | | | | | | 0 |
| 19th— 2 a.m. | | | | | | | | | 0 |
| 6 a.m. | | | | | | | | | 0 |
| 10 a.m. | 11 | 8 | 3 | 3 | 15 | 4 | 4 | 5 | 53 |
| 2 p.m. | 9 | 2 | 12 | | 5 | 13 | 8 | 8 | 57 |
| 6 p.m. | | | | | | | | | 0 |
| 10 p.m. | | | | | | | | | 0 |
| 20th— 2 a.m. | | | | | | | | | 0 |
| 6 a.m. | | | | | | | | | 0 |
| 10 a.m. | 6 | | | | 3 | 4 | | 1 | 14 |
| 2 p.m. | 6 | 7 | 15 | 7 | 14 | 14 | 8 | 14 | 85 |
| 6 p.m. | | | | | | | | | 0 |
| 10 p.m. | | | | | | | | | 0 |
| 21st— 2 a.m. | | | | | | | | | 0 |
| 6 a.m. | | | | | | | | | 0 |
| 10 a.m. | 7 | 1 | 1 | | 2 | 3 | | 3 | 17 |
| 2 p.m. | 9 | | 3 | 2 | 10 | 12 | 5 | 7 | 48 |

TABLE 19.

Blooming of rice in Plot 4.

(Control.)

| Date and time when the number of blooming flowers was counted | Number of blooming flowers | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Panicles | | | | | | | | Total |
| | I | II | III | IV | V | VI | VII | VIII | |
| June 16th— 6 p.m. | | | | | | | | | 0 |
| 10 p.m. | | | | | | | | | 0 |
| 17th— 2 a.m. | | | | | | | | | 0 |
| 6 a.m. | | | | | | | | | 0 |
| 10 a.m. | | | | | | | | | 0 |
| 2 p.m. | 34 | 27 | 7 | | | | | | 68 |
| 6 p.m. | | | | | | | | | 0 |
| 10 p.m. | | | | | | | | | 0 |
| 18th— 2 a.m. | | | | | | | | | 0 |
| 6 a.m. | | | | | | | | | 0 |
| 10 a.m. | | | | | | | | | 0 |
| 2 p.m. | 10 | 19 | 7 | 9 | 3 | 9 | 2 | 7 | 66 |
| 6 p.m. | | | | | | | | | 0 |
| 10 p.m. | | | | | | | | | 0 |
| 19th— 2 a.m. | | | | | | | | | 0 |
| 6 a.m. | | | | | | | | | 0 |
| 10 a.m. | | | | | | | | | 0 |
| 2 p.m. | 15 | 10 | 11 | 8 | 13 | 22 | 13 | 19 | 111 |
| 6 p.m. | | | 1 | | | | | 1 | 2 |
| 10 p.m. | | | | | | | | | 0 |
| 20th— 2 a.m. | | | | | | | | | 0 |
| 6 a.m. | | | | | | | | | 0 |
| 10 a.m. | | | | | | | | | 0 |
| 2 p.m. | 8 | 19 | 10 | 12 | 13 | 18 | 15 | 7 | 102 |
| 6 p.m. | | | | | 1 | 1 | | 4 | 6 |
| 10 p.m. | | | | | | | | | 0 |
| 21st— 2 a.m. | | | | | | | | | 0 |
| 6 a.m. | | | | | | | | | 0 |
| 10 a.m. | | 1 | | | | | 1 | | 2 |
| 2 p.m. | 3 | 9 | 6 | 5 | 17 | 16 | 19 | 15 | 90 |

The results in Tables 16–19 are summarized in the following table.

TABLE 20.

Showing the total number of flowers blooming during the five days.

| Time at which the number of blooming flowers was counted | Plot 1. Lighted continuously | | Plot 2. Darkened by day and lighted at night | | Plot 3. Lighted by day and darkened at night | | Plot 4. Control | |
|---|---|---|---|---|---|---|---|---|
| | Total number of blooming flowers | % | Total number of blooming flowers | % | Total number of blooming flowers | % | Total number of blooming flowers | % |
| 2.00 a.m. | 56 | 14.5 | 212 | 41.1 | **1** | **0.2** | **0** | **0.0** |
| 6.00 a.m. | 57 | 14.7 | 46 | 8.9 | **0** | **0.0** | **0** | **0.0** |
| 10.00 a.m. | 57 | 14.7 | **9** | **1.7** | 86 | 20.4 | 2 | 0.4 |
| 2.00 p.m. | 111 | 28.7 | **5** | **1.0** | 334 | 79.3 | 437 | 97.8 |
| 6.00 p.m. | 54 | 14.0 | **38** | **7.4** | 0 | 0.0 | 8 | 1.8 |
| 10.00 p.m. | 52 | 13.4 | 206 | 39.9 | **0** | **0.0** | **0** | **0.0** |

Note: Gothic figures indicate the number and percentage of flowers which bloomed in the dark.

Glancing through the results of the experiment, while in the control plot almost all of the flowers had finished blooming between 10 a.m. and 2 p.m., in Plot 1 the blooming took place successively during day and night, and in Plot 2, many flowers bloomed between 6 p.m. and 2 a.m. From these data it can easily be gathered that the light and the blooming are in close relation with each other.

Besides Taichu No. 65, Toyokuni and Iwata-asahi were also used as materials for the experiment in Plot 2. The results obtained from these materials are shown in Table 21. It is clearly seen that in these varieties as well, the same tendencies with regard to the blooming time as in the case of Taichu No. 65 are observable, and lead the author to conjecture that the phenomena mentioned above are not peculiarities limited to Taichu No. 65.

TABLE 21.

Showing the total number of flowers blooming during the five days in Plot 2 with varieties Toyokuni and Iwata-asahi.

| Time at which the number of blooming flowers was counted | Toyokuni | | Iwata-asahi | |
|---|---|---|---|---|
| | Total number of blooming flowers | % | Total number of blooming flowers | % |
| 2.00 a.m. | 133 | 54.7 | 82 | 47.7 |
| 6.00 a.m. | 8 | 3.3 | 10 | 5.8 |
| 10.00 a.m. | 1 | 0.4 | 0 | 0.0 |
| 2.00 p.m. | 0 | 0.0 | 2 | 1.2 |
| 6.00 p.m. | 2 | 0.8 | 5 | 2.9 |
| 10.00 p.m. | 99 | 40.7 | 73 | 42.4 |

From the above tables, it is possible to conclude that the alternating change of light especially of day and night plays an important role on the blooming of rice flowers.

## EXPERIMENT XXXIII

This experiment was carried out to know how far the blooming time is affected when the morning rays are intercepted. The materials were kept in the darkened room from the early evening of the previous day; on the day of the experiment, they were taken out and exposed to the sunlight from 8, 9 and 10 a.m. respectively, and their blooming phenomena observed.

The variety used for this experiment was Taichu No. 65, and 5 panicles were supplied for investigation. The results are given in Table 22.

TABLE 22.

Blooming of rice flowers when morning light comes late.

| Time at which plants were transferred from the darkened room to the open | Time when blooming begins | Number of blooming flowers in the given time | | | | | | | | | | | Average blooming time |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | –10.00 a.m. | 10.30 a.m. | 11.00 a.m. | 11.30 a.m. | 12.00 m. | 12.30 p.m. | 1.00 p.m. | 1.30 p.m. | 2.00 p.m. | 3.00 p.m. | 4.00 p.m. | Total | |
| 8.00 a.m. | Panicle I 11.06 a.m. | | | | 4 | 22 | 5 | | | | | | 31 | |
| | " II 10.29 a.m. | 1 | 8 | 8 | 11 | 2 | | | | | | | 30 | |
| | " III 11.28 a.m. | | | | 1 | 31 | 3 | | 1 | | | | 36 | |
| | " IV 10.40 a.m. | | 4 | 8 | 26 | 3 | | | | | | | 41 | |
| | " V 10.38 a.m. | | 1 | 3 | 31 | 3 | 1 | | | | | | 39 | |
| | Total | 1 | 13 | 24 | 121 | 16 | 1 | 1 | | | | | 177 | 11.39 a.m. |
| | % | 0.6 | 7.3 | 13.6 | 68.4 | 9.0 | 0.6 | 0.6 | | | | | 100 | |
| 9.00 a.m. | Panicle I 10.58 a.m. | | 1 | 11 | 8 | 7 | | | | | | | 27 | |
| | " II 10.31 a.m. | | 2 | 10 | 21 | 7 | | | | 1 | | | 41 | |
| | " III 11.01 a.m. | | | 10 | 12 | 3 | | | 1 | | | | 26 | |
| | " IV 11.50 a.m. | | | | 25 | 1 | | | | | | | 26 | |
| | " V 11.08 a.m. | | | 10 | 24 | 6 | | | | | | | 40 | |
| | Total | | 3 | 41 | 90 | 24 | | | 1 | 1 | | | 160 | 11.42 a.m. |
| | % | | 1.9 | 25.6 | 56.3 | 15.0 | | | 0.6 | 0.6 | | | 100 | |

| | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 10.00 a.m. | Panicle I | 11.26 a.m. | | | 2 | 22 | 4 | | | | | | 28 | |
| | " II | 11.20 a.m. | | | 6 | 19 | 3 | | | | | | 28 | |
| | " III | 11.08 a.m. | | | 2 | 25 | 9 | | | | | | 36 | |
| | " IV | 11.55 a.m. | | | | 20 | 11 | 1 | | | | | 32 | |
| | " V | 11.58 a.m. | | | | 5 | 16 | | | | | | 21 | |
| | Total | | | | 10 | 91 | 43 | 1 | | | | | 145 | 11.52 a.m. |
| | % | | | | 6.9 | 62.8 | 29.7 | 0.7 | | | | | 100 | |
| In the darkened room (Not transferred) | Panicle I | 12.15 p.m. | | | | | 11 | 8 | 3 | 7 | 2 | | 31 | |
| | " II | 12.20 p.m. | | | | | 17 | 6 | 8 | 1 | | | 32 | |
| | " III | 12.33 p.m. | | | | | | 8 | 10 | 4 | 2 | | 24 | |
| | " IV | 12.20 p.m. | | | | | 15 | 4 | 1 | 3 | | | 23 | |
| | " V | 12.15 p.m. | | | | | 17 | 6 | 4 | 4 | | 1 | 32 | |
| | Total | | | | | | 60 | 32 | 26 | 19 | 4 | 1 | 142 | 12.49 p.m. |
| | % | | | | | | 42.3 | 22.5 | 18.3 | 13.4 | 2.8 | 0.7 | 100 | |
| Control (Sunrise: 5.49 a.m.) | Panicle I | 10.06 a.m. | 4 | 5 | 4 | 11 | 2 | | | | | | 26 | |
| | " II | 10.44 a.m. | | 11 | 8 | 5 | 3 | | | | | | 27 | |
| | " III | 10.50 a.m. | | 1 | 11 | 12 | 9 | | | | | | 33 | |
| | " IV | 10.05 a.m. | 1 | 5 | 3 | 17 | 1 | 1 | | | | | 28 | |
| | " V | 10.04 a.m. | 1 | 1 | 7 | 9 | 13 | | | | | | 31 | |
| | Total | | 6 | 23 | 33 | 54 | 28 | 1 | | | | | 145 | 11.31 a.m. |
| | % | | 4.1 | 15.9 | 22.8 | 37.2 | 19.3 | 0.7 | | | | | 100 | |

According to the results of these observations, the flowers that were exposed early to the sunlight, began to bloom early and those which were taken out later, bloomed later; in the extreme case where the flowers were not exposed to the light at all, these bloomed much later. The temperature in the darkened room was about 1°C. higher than that of the outside, consequently the continual effect of the temperature is considered to be greater in the inside than in the outside; nevertheless the fact that the blooming time is relatively late may be said to be mainly due to the effect of light upon blooming.*

## EXPERIMENT XXXIV

It was presumed that if the plants were exposed to light from the previous evening, contrary to Experiment XXXIII, they would bloom earlier than the natural blooming time. This presumption was proved by Experiment XXXIV.

The material was the same as for Experiment XXXIII, and was illuminated by two 60 w electric bulbs at about 1 meter's distance from the previous night till dawn out-of-doors. The results are given in Table 23.

The plants which were lighted from the previous night began to bloom at 9.08 a.m., the number of flowers which bloomed before 10.30 a.m. being 50 (33.9%) out of 147, while those in the control plot began to bloom at 10.06 a.m. and the number of flowers which bloomed before 10.30 a.m. was only 9 (5.8%) out of 155. As the environmental factors of the two plots were regarded to be practically the same except for lighting conditions, it is possible to say that the above mentioned difference is caused by exposure or non-exposure of the plants to light during the previous night; that is to say, the light has a possitive effects upon the blooming of rice flowers.

It will have become clear from the results of Experiments XXXII–XXXIV, that the time of blooming of rice flowers is markedly influenced by the conditions under which the exposure to light takes place.

---

* Light is not absolutely necessary for blooming since the author has observed blooming of rice flowers to take place in a constantly darkened room.

TABLE 23.

Blooming of rice flowers exposed to light throughout the previous night.

| | Time when blooming begins | Number of blooming flowers in the given time | | | | | | | | Average blooming time |
|---|---|---|---|---|---|---|---|---|---|---|
| | | —9.30 a.m. | 9.30—10.00 a.m. | 10.00—10.30 a.m. | 10.30—11.00 a.m. | 11.00—11.30 a.m. | 11.30—12.00 m. | 12.00—12.30 p.m. | Total | |
| Lighted throughout previous night | Panicle I 9.20 a.m. | 3 | 13 | 7 | 12 | | | | 35 | |
| | " II 9.34 a.m. | | 6 | 10 | 17 | 2 | | | 35 | |
| | " III 9.08 a.m. | 1 | 2 | 2 | 8 | | | | 13 | |
| | " IV 10.04 a.m. | | | 3 | 36 | 1 | | 1 | 41 | |
| | " V 9.45 a.m. | | 2 | 1 | 18 | 1 | 1 | | 23 | |
| | Total | 4 | 23 | 23 | 91 | 4 | 1 | 1 | 147 | 10.30 a.m. |
| | % | 2.7 | 15.6 | 15.6 | 61.9 | 2.7 | 0.7 | 0.7 | 100 | |
| Control | Panicle I 10.06 a.m. | | | 7 | 25 | | | | 32 | |
| | " II 10.10 a.m. | | | 2 | 16 | 11 | | | 29 | |
| | " III 10.40 a.m. | | | | 28 | 5 | 1 | 1 | 35 | |
| | " IV 10.40 a.m. | | | | 18 | 7 | 1 | | 26 | |
| | " V 10.40 a.m. | | | | 32 | 1 | | | 33 | |
| | Total | | | 9 | 119 | 24 | 2 | 1 | 155 | 10.49 a.m. |
| | % | | | 5.8 | 76.8 | 15.5 | 1.3 | 0.6 | 100 | |

### 2. *Effect of temperature upon time of blooming*

As an important environmental condition which affects the blooming of rice flowers, the temperature has been hitherto considered most attentively. It is natural to think that blooming should require a certain range of temperature. In rice plant the minimum temperature for blooming is 15°C. (AKEMINE 1914 and TAKIGUCHI 1930) and the maximum temperature 50°C. (AKEMINE 1914 and NOGUCHI 1927-a); the optimum temperature is reported by AKEMINE (1914) as 35°–40°C., and 30°C. by NOGUCHI (1927-a) and also reported as between 28°–30°C. by TAKIGUCHI (1930). It is easily conceivable that in natural surroundings, the higher the temperature, the more lively is the blooming and therefore that a close relation exists between the temperature and the blooming time of the day. As to the reason why the flower does not bloom until it reaches a certain hour, AKEMINE (1914) said that it needs to be in a temperature above a certain degrees for a set period of time. ISO (1913) presumed that the flowers need a periodic change of temperature for blooming because the flowers do not bloom until a certain time of day is reached even at a higher temperature as 23°C. which is common all day in Taihoku.

In the following Experiment XXXV the author will consider the relation between periodic change of temperature and blooming time of rice flowers during the day.

## EXPERIMENT XXXV

Plants of the variety Taichu No. 65 was cultivated in pots as material which were divided into three plots following the condition of exposures to light as in the case of Experiment XXXII: the first plot continuously lighted (Plot 1), the second plot darkened by day and lighted at night (Plot 2) and the third for control (Plot 3). The experiment was begun on October 29th, and the number of flowers that bloomed were counted every four hours for 6 days from 10 p.m. on October 31st to 10 p.m. on November 6th. 10 panicles of 4 plants were supplied to every plot and the results of the observations on 8 panicles which developed more or less similar in growth are given. As it was fine throughout this experiment, the variations in temperature during the day and night were rather greater compared to those in Experiment XXXII (cf. Appendix Tables II, IV and VI). The results of observations are shown in Tables 24-26.

TABLE 24.

Blooming of rice in Plot 1. (Lighted continuously.)

| Date and time when the numbe of blooming flowers was counted | Number of blooming flowers | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Panicles | | | | | | | | Total |
| | I | II | III | IV | V | VI | VII | VIII | |
| November 1st— 2 a.m. | | | | | | | | | 0 |
| 6 a.m. | | | | | | | | | 0 |
| 10 a.m. | | | | | 7 | | | | 7 |
| 2 p.m. | | 1 | 10 | | | 19 | | 4 | 34 |
| 6 p.m. | | | | | 3 | | 3 | | 6 |
| 10 p.m. | | | | | | 1 | | | 1 |
| 2nd— 2 a.m. | | | | | | | | | 0 |
| 6 a.m. | | | | | | | | | 0 |
| 10 a.m. | | | | | | | | | 0 |
| 2 p.m. | 9 | 3 | 4 | 8 | | 5 | 5 | 5 | 39 |
| 6 p.m. | 3 | | | 5 | | | 4 | | 12 |
| 10 p.m. | | 1 | | 2 | | 1 | 1 | | 5 |
| 3rd— 2 a.m. | | | | | | | | | 0 |
| 6 a.m. | | | | | | | | | 0 |
| 10 a.m. | | | | | | | | | 0 |
| 2 p.m. | 13 | 7 | 5 | 11 | 3 | 5 | 5 | 3 | 52 |
| 6 p.m. | 5 | 8 | 3 | 2 | | 1 | 2 | 4 | 25 |
| 10 p.m. | 2 | | | 1 | | | | | 3 |
| 4th— 2 a.m. | 1 | | | | | | | | 1 |
| 6 a.m. | | 1 | | | | | | | 1 |
| 10 a.m. | | | | | | | | | 0 |
| 2 p.m. | 7 | 5 | 1 | 8 | 13 | | | 4 | 38 |
| 6 p.m. | 1 | | 3 | 4 | 7 | | 2 | 2 | 19 |
| 10 p.m. | 1 | | | | | | | | 1 |
| 5th— 2 a.m. | | | | | | | | | 0 |
| 6 a.m. | | | 1 | | | | | | 1 |
| 10 a.m. | | | | | | | | | 0 |
| 2 p.m. | 1 | 1 | | | 1 | | | | 3 |
| 6 p.m. | 1 | 2 | | | | | 3 | | 6 |
| 10 p.m. | | | 1 | | | | | | 1 |
| 6th— 2 a.m. | | | | | | | | 1 | 1 |
| 6 a.m. | | | | | | | | | 0 |
| 10 a.m. | 1 | | | | | | | | 1 |
| 2 p.m. | 1 | | | 2 | | | | | 3 |
| 6 p.m. | 1 | | | | | | 2 | | 3 |
| 10 p.m. | | | | | | | | | 0 |

TABLE 25.

Blooming of rice in Plot 2. (Darkened in the daytime and lighted at night.)

| Date and time when the number of blooming flowers was counted | Number of blooming flowers | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Panicles | | | | | | | | Total |
| | I | II | III | IV | V | VI | VII | VIII | |
| November 1st— 2 a.m. | | | | | | | | | 0 |
| 6 a.m. | | | | | | | | | 0 |
| 10 a.m. | | | | | | | | | 0 |
| 2 p.m. | | 1 | 5 | 4 | 5 | 1 | 3 | | 19 |
| 6 p.m. | 3 | 5 | 6 | | 5 | | 5 | | 24 |
| 10 p.m. | | | | | 1 | | 2 | | 3 |
| 2nd – 2 a.m. | | 1 | | 4 | | | | | 5 |
| 6 a.m. | | | 1 | 2 | | | | | 3 |
| 10 a.m. | | | | | | | | | 0 |
| 2 p.m. | 2 | 2 | | | 2 | 2 | | | 8 |
| 6 p.m. | 11 | 12 | 4 | 5 | 7 | | 6 | | 45 |
| 10 p.m. | 9 | 12 | 3 | 6 | 9 | 3 | 2 | 1 | 45 |
| 3rd – 2 a.m. | | 1 | | | 1 | | | | 2 |
| 6 a.m. | | | | | | | | | 0 |
| 10 a.m. | 2 | | | | | | 1 | | 3 |
| 2 p.m. | | | | 2 | 2 | 4 | | 3 | 11 |
| 6 p.m. | 1 | 2 | | 2 | 1 | 1 | 3 | 5 | 15 |
| 10 p.m. | 2 | 1 | | | | | | 1 | 4 |
| 4th— 2 a.m. | 1 | | | | 1 | | | | 2 |
| 6 a.m. | | | | | 1 | | | | 1 |
| 10 a.m. | | | | | | 1 | | 1 | 2 |
| 2 p.m. | | 1 | | 4 | 4 | | | 6 | 15 |
| 6 p.m. | 1 | | | | 3 | 1 | | | 5 |
| 10 p.m. | | | 1 | | 1 | | | | 2 |
| 5th— 2 a.m. | 2 | 1 | | | 1 | | 1 | | 5 |
| 6 a.m. | | | | | | | | | 0 |
| 10 a.m. | | | | | | | | | 0 |
| 2 p.m. | | | 1 | 1 | 1 | | | | 3 |
| 6 p.m. | | 1 | 2 | | 5 | 2 | 4 | 4 | 18 |
| 10 p.m. | | | 1 | | | 5 | | 6 | 12 |
| 6th – 2 a.m. | 1 | | 4 | | | 1 | 1 | | 7 |
| 6 a.m. | 1 | | 2 | | | | | 1 | 4 |
| 10 a.m. | | | | | | 1 | | | 1 |
| 2 p.m. | | | | | | | 3 | | 3 |
| 6 p.m. | 1 | | | 1 | | | | | 2 |
| 10 p.m. | | | | | | | | | 0 |

TABLE 26.

Blooming of rice in Plot 3. (Control.)

| Date and time when the number of blooming flowers was counted | Number of blooming flowers | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Panicles | | | | | | | | Total |
| | I | II | III | IV | V | VI | VII | VIII | |
| November 1st— 2 a.m. | | | | | | | | | 0 |
| 6 a.m. | | | | | | | | | 0 |
| 10 a.m. | | | | | | | | | 0 |
| 2 p.m. | 17 | 9 | 7 | 7 | | 6 | 10 | | 56 |
| 6 p.m. | | | | | | | | | 0 |
| 10 p.m. | | | | | | | | | 0 |
| 2nd— 2 a.m. | | | | | | | | | 0 |
| 6 a.m. | | | | | | | | | 0 |
| 10 a.m. | | | | | | | | | 0 |
| 2 p.m. | 36 | 27 | 21 | 16 | 2 | 22 | 11 | 7 | 142 |
| 6 p.m. | | | 1 | | | | | | 1 |
| 10 p.m. | | | | | | | | | 0 |
| 3rd— 2 a.m. | | | | | | | | | 0 |
| 6 a.m. | | | | | | | | | 0 |
| 10 a.m. | | | | | | | | | 0 |
| 2 p.m. | 11 | 9 | 17 | 15 | 16 | 15 | 12 | 9 | 104 |
| 6 p.m. | | | | | | | | | 0 |
| 10 p.m. | | | | | | | | | 0 |
| 4th— 2 a.m. | | | | | | | | | 0 |
| 6 a.m. | | | | | | | | | 0 |
| 10 a.m. | | | | | | | | | 0 |
| 2 p.m. | 10 | 7 | 17 | 10 | 21 | 10 | | 21 | 96 |
| 6 p.m. | | | 1 | 2 | 1 | | | | 4 |
| 10 p.m. | | | | | | | | | 0 |
| 5th— 2 a.m. | | | | | | | | | 0 |
| 6 a.m. | | | | | | | | | 0 |
| 10 a.m. | | | | | | | | | 0 |
| 2 p.m. | 1 | 5 | 8 | 5 | 12 | 6 | | 9 | 46 |
| 6 p.m. | | | 1 | | | | | | 1 |
| 10 p.m. | | | | | | | | | 0 |
| 6th— 2 a.m. | | | | | | | | | 0 |
| 6 a.m. | | | | | | | | | 0 |
| 10 a.m. | | | | | | | | | 0 |
| 2 p.m. | | 1 | | | 1 | | | 3 | 5 |
| 6 p.m. | | 1 | 1 | | | | | | 2 |
| 10 p.m. | | | | | | | | | 0 |

The results shown in Tables 24–26 are summarized as follows.

TABLE 27.

Showing the total number of flowers blooming during the six days.

| Time at which the numer of blooming flowers was counted | Plot 1. Lighted continuously | | Plot 2. Darkened by day and lighted at night | | Plot 3. Control | |
|---|---|---|---|---|---|---|
| | Total number of blooming flowers | % | Total number of blooming flowers | % | Total number of blooming flowers | % |
| 2.00 a.m. | 2 | 0.8 | 21 | 7.8 | **0** | **0.0** |
| 6.00 a.m. | 2 | 0.8 | 8 | 3.0 | **0** | **0.0** |
| 10.00 a.m. | 8 | 3.0 | **6** | **2.2** | 0 | 0.0 |
| 2.00 p.m. | 169 | 64.3 | **59** | **21.9** | 449 | 98.2 |
| 6.00 p.m. | 71 | 27.0 | **109** | **40.5** | 8 | 1.8 |
| 10.00 p.m. | 11 | 4.2 | 66 | 24.5 | **0** | **0.0** |

Note: Gothic figures indicate the number and percentage of flowers which bloomed in the dark.

According to the above experimental results, in the control plot almost all the flowers which would bloom during the day, bloom successively between 10 a.m. and 2 p.m., the frequency values being 98.2%; in Plot 1 also a large number of flowers bloomed during that time, the frequency, however, is less than in the former case, where it reaches 64.3%. In Plot 2 the blooming was somewhat delayed and the frequency maximum is found between 2 p.m. and 6 p.m., yet the number of blooming flowers in that time is less than half of the total, showing a greater dispersion of the blooming than in the case of Plot 1.

Comparing the result of Experiment XXXV with that of Experiment XXXII, an outstanding difference between the percentages of the bloom figures in the given times is found, although in both experiments the light condition were the same in Plot 1 as well as in Plot 2. This shows that there some other important factors, other than light, affect the blooming. According to the author's opinion the difference of temperature may be noticed here.

Examining in the first place Plot 1 in Experiment XXXII, the lowest temperature is 24.8°C. at 6-7 a.m., and the highest, 27.6°C. at 2 p.m., the difference being 2.8°C.; in Experiment XXXV, on the other hand, the lowest is 23.0°C. at 7 a.m. and the highest, 32.3°C. at 2 p.m., showing the difference 9.3°C. (cf. Appendix Tables I and II). In other words, though the general tendencies of the daily change in temperature resemble each other, the difference between the maximum and the minimum was much greater in the latter case. Moreover, in both cases, the greatest number of flowers bloom between 10 a.m. and 2 p.m., the time at which the temperature rises to the maximum in the given day, but in the former, the frequency value of blooming flowers is only 28.7% and in the remaining flowers the blooming is spread almost equally over the different times (cf. Table 20). In the latter, the frequency number of flowers that bloomed between 10 a.m. and 2 p.m. is 64.3%, and 27% between 2 and 6 p.m. (cf. Table 27).

Throughout the observations mentioned above, a parallelism can be found between the dispersion of blooming, in frequency, and the daily change of temperature (Figs. 2-3).

Fig. 2.
Variation in temperature and dispersion of blooming during the day in Plot 1 of Experiment XXXII.

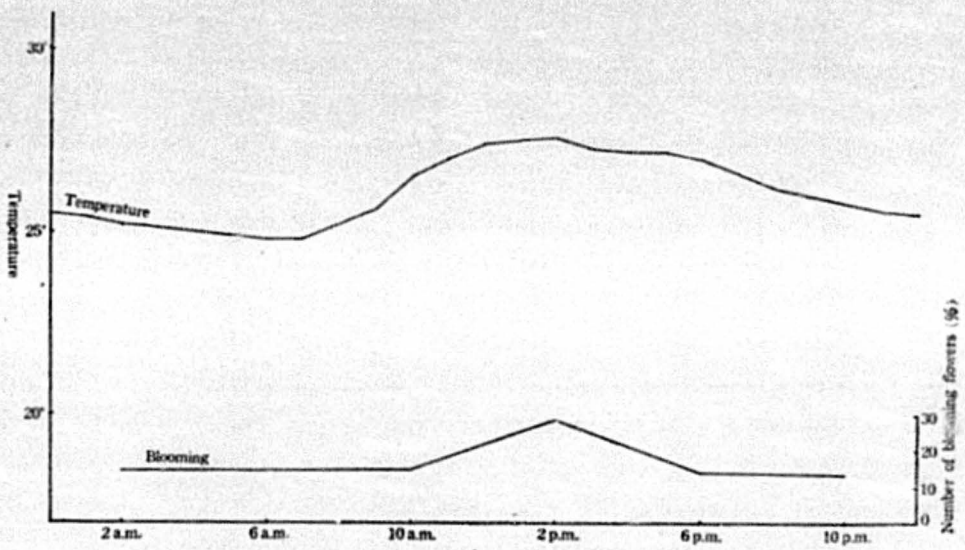
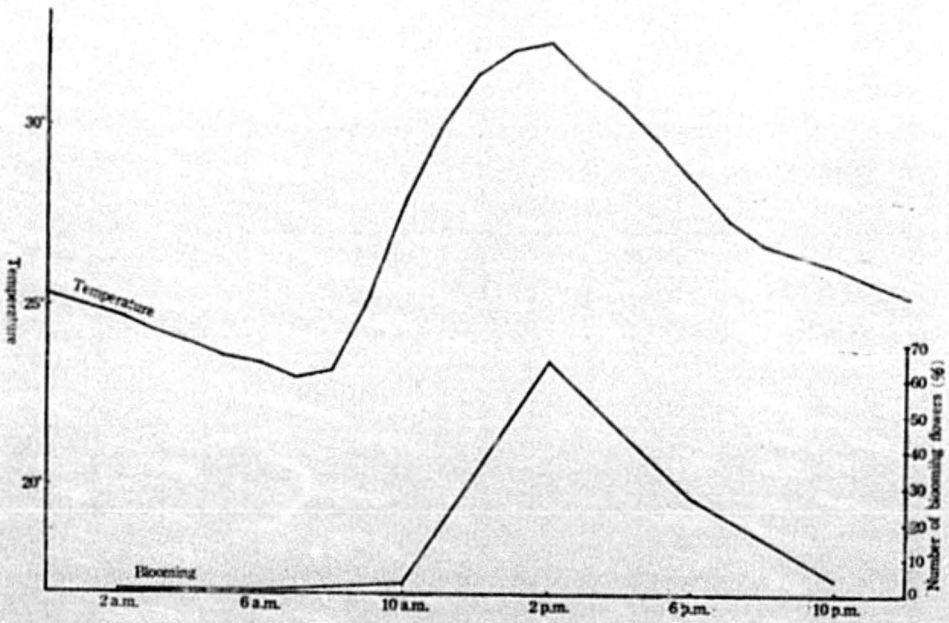


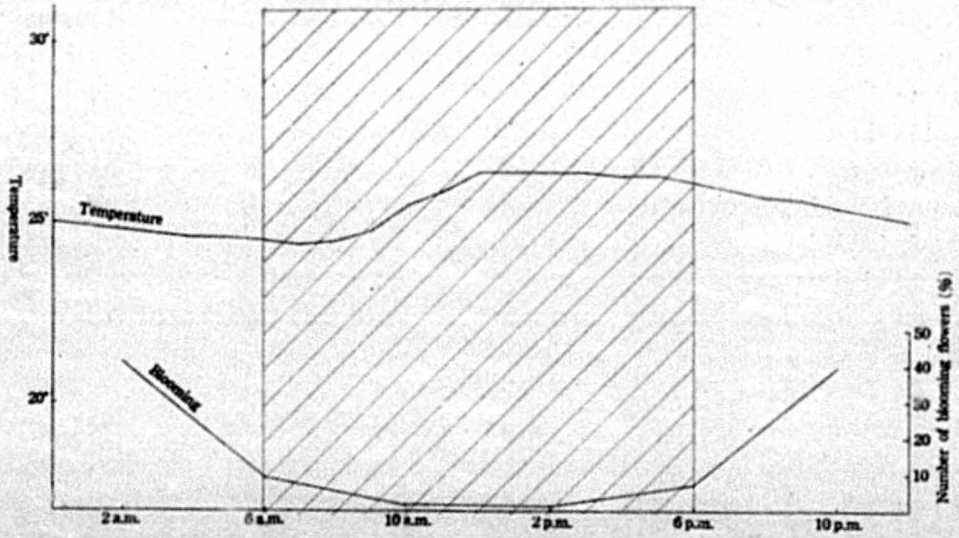
Fig. 3.
Variation in temperature and dispersion of blooming during the day in Plot 1 of Experiment XXXV.




As for the figures in Plot 2, in Experiment XXXII the lowest temperature was 24.4°C. at 7 a.m., the highest 26.4°C. between 12 m. and 3 p.m., the difference between them being 2°C., while in Experiment XXXV, the lowest is 22.3°C. at 8 a.m., and the highest, 30.7°C. at 2 p.m., the difference of them being 8.4°C. (cf. Appendix Tables III and IV). In the former, 89.9% of the total number of flowers bloomed between 6 p.m. and 6 a.m. under the exposure to light, and 10.1% bloomed in the dark (cf. Table 20). In Experiment XXXV, the flowers bloomed between 6 a.m. and 6 p.m. (in the dark) were 64.6% and 35.3% bloomed between 6 p.m. and 6 a.m. under the exposure to the light (cf. Table 27).

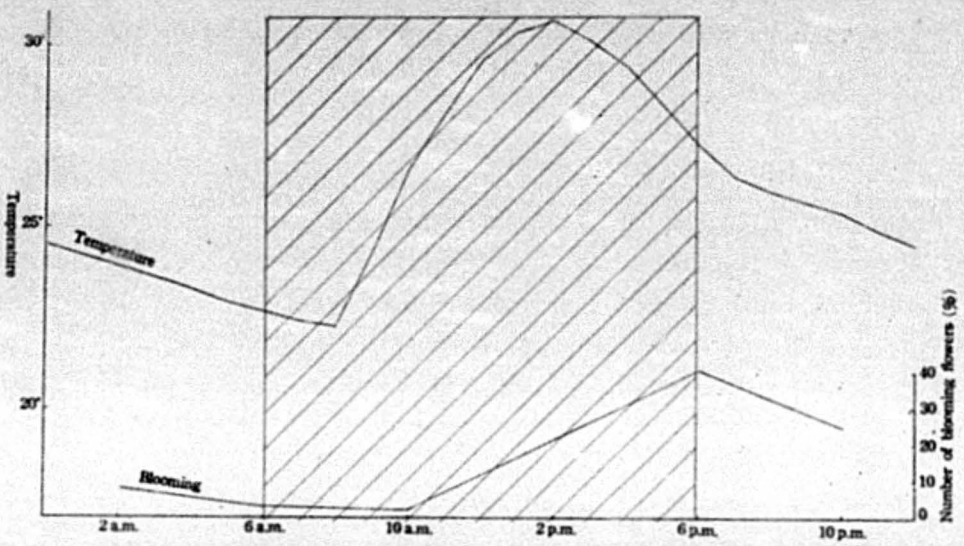
The states mentioned above are graphically shown in Figs. 4 and 5. It is clear from these experiments that the temperature plays an important role on the blooming of rice flowers as already mentioned by many authors, namely the frequency number of blooming in rice flowers is proportionate to the temperature; in other words, when the temperature becomes higher, the number of blooming flowers increases, so far as the temperature concerned.

Fig. 4. Variation in temperature and dispersion of blooming during the day in Plot 2 of Experiment XXXII.




Note: The space covered with oblique lines shows the darkened period.

Fig. 5. Variation in temperature and dispersion of blooming during the day in Plot 2 of Experiment XXXV.



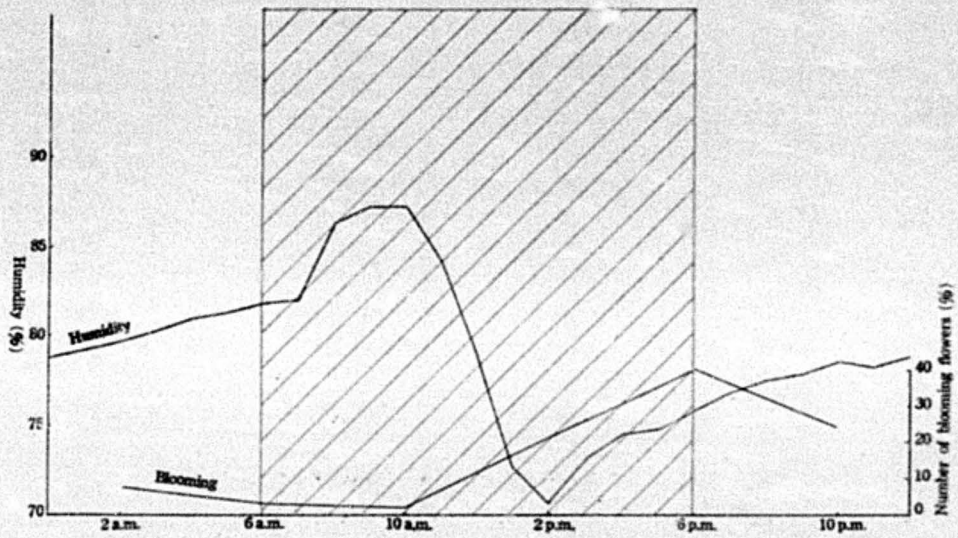

### 3. *Effect of humidity upon time of blooming*

According to Iso (1913), SUZUTA and TOMURA (1922), there is no close correlation between the blooming of rice flowers and humidity. AKEMINE (1914) also expressed the same opinion, and added that when the temperatures

were the same, blooming occurs more favourably in conditions of lower humidity. According to NOGUCHI (1925) in rice flowers the frequency numbers of blooming decrease in the air saturated with humidity but no difference is found regarding the full blooming time. NOGUCHI (1927-c) also says that extreme dryness prevents the process of blooming or sometimes produces confusion in their blooming, but such conditions seldom occur in a natural environment. Consequently the effect of humidity upon blooming under natural conditions is considered to be comparatively small. However, NOGUCHI (1925, 1927-c) recognized that the full blooming time in a day is accompanied by rapid decrease in humidity and said that the rapid decrease in humidity hastens blooming. POGGENDORFF (1932) also said that the change in humidity had something to do with the blooming.

In Experiment XXXV, the humidity was investigated with Plot 2 which was darkened by day and lighted at night. The result is given in Appendix Table VII. It is shown from that table that the highest humidity of the day is 87.2% between 9 and 10 a.m. and began to decrease rapidly after that time, presenting 70.7% at 2 p.m. and then beginning to increase again. The number of blooming flowers have been found to represent only 21.9% of the total between 10 a.m. and 2 p.m., between these times the humidity was decreasing and the full blooming period came after 2 p.m. when the humidity began to increase (Fig. 6).

Fig. 6.
Variation in humidity and dispersion of blooming during the day in Plot 2 of Experiment XXXV.




Judging from the results, arrival at the full blooming period does not necessarily accompany rapid decrease in humidity, but the flowers bloom even

at the time when the humidity is increasing if the other environmental factors are fovourable. According to NOGUCHI (1925) the blooming proceeds in the air saturated with humidity, showing no difference regarding the full blooming time as compared with that under natural conditions. It may be concluded from this fact that full blooming time does not depend upon the change of humidity, for there must be some difference between the full blooming time in the air saturated with humidity and that under natural conditions if the decrease in humidity can hasten the blooming of rice flowers.

NAKANO (1929) and ISEDA (1930) also observed that the blooming of rice flowers takes place when the humidity decreases. Under natural conditions, however, the change of humidity has a close relation to the changes of temperature and, namely, that except for days with special weather conditions, it usually follows a rise in temperature and a decrease in humidity, so in natural blooming a rapid decrease in humidity seems to bring about the full blooming, but this is largely owing to the rise in the temperature, while the decrease in humidity is considered not to affect it markedly.

## IV. PHYSICAL MECHANISM OF THE OPENING OF RICE FLOWERS

The author described in Chapters II and III the peculiar characteristics found in the blooming of rice flowers with special reference to the time of day of blooming. In the following sections the author will describe the results in detail obtained in his experiments on the physical mechanism of blooming. The variety used as material for this experiment was Taichu No. 65, and the experiment was carried out on June 1938.

### 1. *Change in size of the lodicules*

Many investigators agree in the opinion that the opening of the flowers in gramineous plants is caused by swelling of the lodicules, and in rice it has already been reported by NAKAO (1911) and AKEMINE (1914). The author in the hope of proving this, has made some observations on the change of size in the lodicules before and after blooming.

#### METHOD

The lodicules were measured at 4 p.m. on the day previous to blooming, at 7.30 a.m., 8.30 a.m., 9.30 a.m. respectively on the day of blooming,* at the

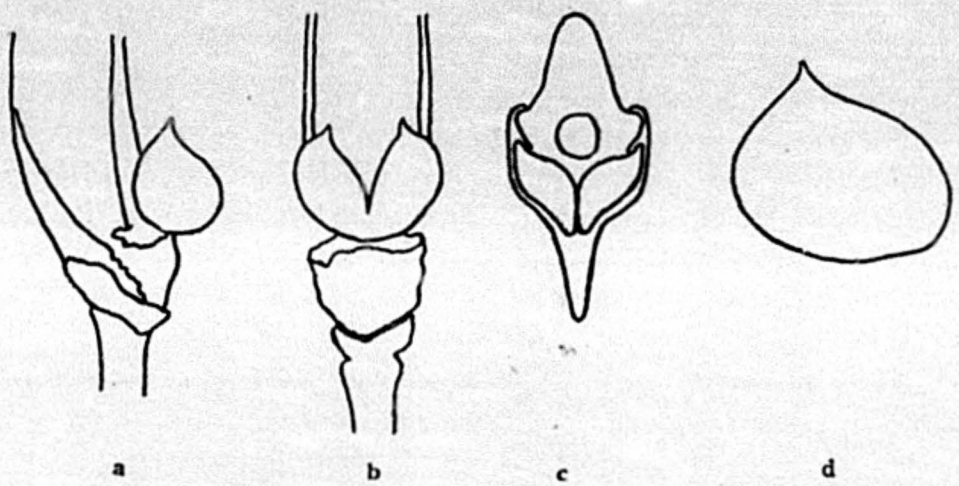
* The flowers which would bloom on that day had already been chosen by naked eyes.

natural blooming time and after closing. These investigations were carried out in the place outside the house. The author also investigated separately the lodicules of the flowers, the blooming of which had been hastened by artificial means, in order to ascertain how they had changed, by taking some of the materials into the house at 7 a.m., 8 a.m. and 9 a.m. The observation in this case, has been made on the flowers that bloomed within 30 minutes of transference. As it was impossible to measure the changes in size of the lodicules on the same flowers, the investigation was carried out on 10 flowers in each plot and the averages for these were duly noted. An ocular micrometer was used for measuring.

## RESULTS OF THE EXPERIMENTS

To refer briefly to the position and shape of the lodicules before describing their changes in size, it may be stated that in the rice plant the lodicules of the flower are two white, semitransparent and soft tissues, the bottom part of which are joined to the margins of the palet at its base (ARBER 1934). When viewed from the straight side, the top is pointed and presents a somewhat distorted chestnut-shape, while the middle is thick and the edge very thin. The two lodicules meet one of their edges forming the letter V while their outer sides face towards the inner side of the lemma. The other edge is held between both glumes (Fig. 7).

Fig. 7.
Showing the position and shape of lodicules.




a. Side view, lemma removed.
b. Front view, lemma removed.
c. Cross section of the flower near the base.
d. Straight side view of a lodicule.

From the measurements, it becomes clear, as shown in Table 28, that there was no conspicuous change in the length of the lodicules since the previous evening, but their width and thickness gradually became greater as the time went on and swelled suddenly at the time of blooming.

TABLE 28.

The size of lodicule.

| | At 4 p.m. of the day previous to blooming | At 7.30 a.m. on the day of blooming | At 8.30 a.m. on the day of blooming | At 9.30 a.m. on the day of blooming | At blooming time (about 10.30 a.m.) | Shortly after the closing |
|---|---|---|---|---|---|---|
| Length (mm) | 1.19 | 1.19 | 1.24 | 1.23 | 1.24 | 1.18 |
| % | 100 | 100 | 104 | 103 | 104 | 99 |
| Width (mm) | 0.90 | 1.01 | 1.05 | 1.04 | 1.20 | 0.97 |
| % | 100 | 112 | 117 | 116 | 133 | 108 |
| Thickness (mm) | 0.39 | 0.43 | 0.45 | 0.48 | 0.58 | — |
| % | 100 | 110 | 115 | 123 | 149 | — |

As shown in this table the width was 0.9 mm on the previous evening which increased to 1.04 mm about an hour before blooming, and then to 1.2 mm at time of blooming; the thickness was 0.39 mm on the previous evening and 0.48mm about an hour before blooming, and 0.58 mm at time of blooming. The increase in width was especially noticeable on one side, i.e., the side opposite to the palet was found greatly swollen downward (Fig. 8).

Fig. 8.
Lodicule at time of blooming.

There was no great change in the length of the lodicules immediately after closing of the glumes, but the width had already considerably diminished and was about the same size as before blooming time; the thickness was still more conspicuously diminished, and it was difficult to measure.

As regards the changes in size of the lodicules, attention hitherto has been paid only to the sudden swelling at the time of blooming, and not to the gradual increase in size before blooming. As shown in the above table, however, the thickness at 9.30 a.m. is larger by 23% than that at 4 p.m. on the previous day. The opening of the glumes should be due chiefly to the sudden

swelling in the width of the lodicules, but judging from the fact that both glumes were already separated before they opened, it is possible that the gradual increase in thickness before blooming has much to do with their separation. The author intends to deal with this in the next section.

The author in the next place will study the change in size of the lodicules in the flowers which bloomed earlier due to transference and compare them with cases of natural blooming. The results of the measurements are given in Table 29.

TABLE 29.

Change in size of lodicules at the time of blooming artificially hastened by transference.

| | Time at which the hastened blooming occurs and size of lodicules | | |
|---|---|---|---|
| | 7 a.m. | 8 a.m. | 9 a.m. |
| Length (mm) | 1.18 | 1.22 | 1.24 |
| % | 99 | 103 | 104 |
| Width (mm) | 1.15 | 1.20 | 1.20 |
| % | 128 | 133 | 133 |
| Thickness (mm) | 0.54 | 0.54 | 0.58 |
| % | 138 | 138 | 149 |

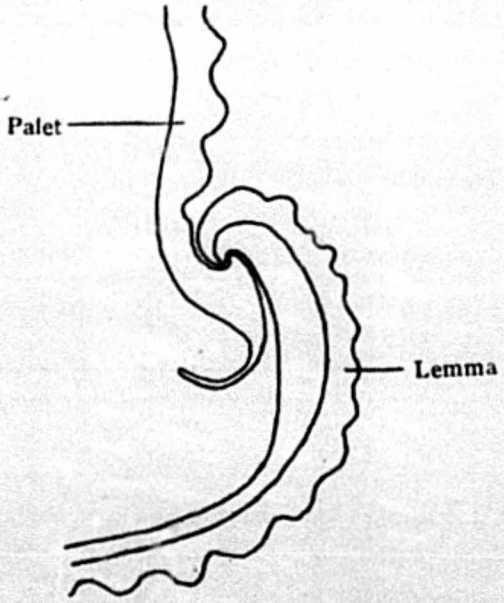
Note: The size at 4 p.m. of the day previous to blooming, as shown in Table 28 was taken as unit, denoting 100 %.

It was found that there was little change in the length of the lodicules, but a great increase in width and thickness appeared as in the case of natural blooming. Since the natural blooming on that day began about at 10.30 a.m. and their width at 9.30 a.m. was 1.04 mm, and their thickness, 0.48 mm at that time (Table 28), it is clear that the above mentioned artificial means worked on the lodicules, making them swell suddenly and caused flowers to bloom.

### 2. *Separation of the hooked glumes and their opening*

Generally the two glumes of rice flowers on the day previous to blooming are firmly joined together by their hook-shaped edges (Fig. 9) and are not easily separated. For this reason, as was already pointed out by TSUJIKAWA (1915), a simple expression such as "through the swelling of the lodicules" is insufficient to explain the mechanism of opening of the glumes. The author therefore wishes to put forward some explanations based on the facts obtained from his observations.

Fig. 9.
Hooking condition of both glumes.




### (1) Separation of the hooked glumes

In dealing with rice flowers, the author usually observed that in many flowers both glumes were already free from each other before blooming time came, and thus he came to think that the sudden swelling of the lodicules might not bring about the separation of the hooked glumes and their opening at the same time, but that at first the gradual separation of the hooked glumes takes place and then is followed by the sudden swelling of the lodicules thus finally bringing about the opening of the glumes. If this is the case, the number of flowers with unhooked glumes should increase when the blooming time of the day approaches. In order to verify this the author carried out the following experiment.

## METHOD OF EXPERIMENT

The author examined the hooking condition of both glumes by pulling them left and right with fingers and forceps. Those already unhooked, opened without any resistance, but those that were not unhooked were difficult to open. The test was divided into 6 plots according to the times when the examination was made: at 4 p.m. of the day previous to blooming, and at 6, 7, 8, 9, 10 a.m. respectively on the day of blooming. For this purpose the flowers

which would bloom on that day were chosen on the afternoon of the previous day. Though the relative strength of hooking is somewhat variable, it was divided broadly into two classes: glumes which were already unhooked, and hooked glumes including the case where the glumes were more or less loosely hooked.

## RESULTS OF THE EXPERIMENT

The results of the experiment are given in Table 30.

TABLE 30.

Percentage of the number of flowers with unhooked glumes at the given time before time of blooming.

| | | Examining time | Number of flowers examined | Number of flowers with hooked glumes | Number of flowers with unhooked glumes | Percentage of unhooked |
|---|---|---|---|---|---|---|
| In the shade outside the house | I (June 22) | 4 p.m. | 20 | 19 | 1 | 5.0 |
| | | 7 a.m. | 20 | 17 | 3 | 15.0 |
| | | 8 a.m. | 20 | 17 | 3 | 15.0 |
| | | 9 a.m. | 20 | 14 | 6 | 30.0 |
| | | 10 a.m. | 20 | 9 | 11 | 55.0 |
| | II (June 23) | 4 p.m. | 20 | 20 | 0 | 0.0 |
| | | 6 a.m. | 20 | 19 | 1 | 5.0 |
| | | 7 a.m. | 20 | 19 | 1 | 5.0 |
| | | 8 a.m. | 20 | 17 | 3 | 15.0 |
| | | 9 a.m. | 20 | 16 | 4 | 20.0 |
| | | 10 a.m. | 20 | 13 | 7 | 35.0 |
| | III (June 25) | 4 p.m. | 100 | 98 | 2 | 2.0 |
| | | 6 a.m. | 20 | 20 | 0 | 0.0 |
| | | 7 a.m. | 20 | 15 | 5 | 25.0 |
| | | 8 a.m. | 20 | 14 | 6 | 30.0 |
| | | 9 a.m. | 20 | 14 | 6 | 30.0 |
| | | 10 a.m. | 20 | 8 | 12 | 60.0 |
| | Total | 4 p.m. | 140 | 137 | 3 | 2.1 |
| | | 6 a.m. | 40 | 39 | 1 | 2.5 |
| | | 7 a.m. | 60 | 51 | 9 | 15.0 |
| | | 8 a.m. | 60 | 48 | 12 | 20.0 |
| | | 9 a.m. | 60 | 44 | 16 | 26.7 |
| | | 10 a.m. | 60 | 30 | 30 | 50.0 |
| Under direct sunshine | (June 25) | 6 a.m. | 20 | 20 | 0 | 0.0 |
| | | 7 a.m. | 20 | 16 | 4 | 20.0 |
| | | 8 a.m. | 20 | 14 | 6 | 30.0 |
| | | 9 a.m. | 20 | 13 | 7 | 35.0 |
| | | 10 a.m. | 20 | 6 | 14 | 70.0 |

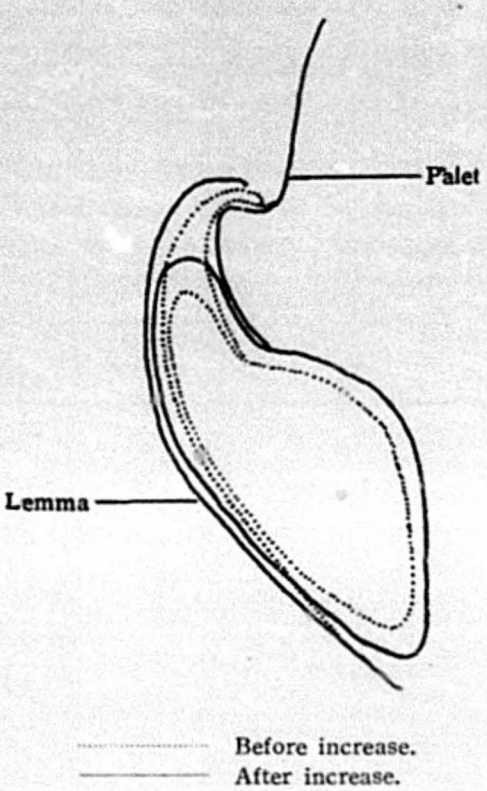
Note: 4 p.m. refers to the previous day.

According to the above table, it will be seen that the number of unhooked flowers varies according to the hour of the day or, in the same hour, to environmental conditions; that is, flowers which were in the direct sunshine showed an early separation of hooking compared to those which were in the shade. This corresponds to the fact that, in the former, blooming occurs usually earlier than in the latter case. In other words, of course from the previous day of blooming till in the early next morning, the number of unhooked flowers was very small, but it increased gradually, and the frequencies of the unhooked flowers became about twice per cent as many at 10 a.m. than at 9 a.m.

From the above fact it is believed that in rice flowers the unhooking of both glumes takes place previous to their opening. Probably in the flowers which unhooked early the blooming may take place early, but the time-lapse between unhooking and opening will not be always definite.

What then, is the direct cause of the occurrence of unhooking? As already remarked, a part of the lodicules is held between both glumes (Fig. 7-c) and the lodicules gradually increase their size before blooming; for example, according to one of the author's experiments, at 9.30 a.m. it had increased by 0.09 mm (23%) in thickness and by 0.14 mm (16%) in width as compared to the size at 4 p.m. of the previous day (Table 28). It is not difficult to assume that this increase in thickness and width necessarily enlarges the space between both glumes and loosens the hooking. The illustration, diagrammatically shown in Fig. 10, will explain this process.

Fig. 10.
Showing the relation between increase in size of lodicule before blooming time and the hooking state of both glumes.



Thus the lemma is pushed and expanded outwards. As a result, the flower gradually increases in thickness and appears to be slightly swollen as the blooming time approaches, reaching the maximum at the blooming period, as is shown numerically in Table 31.

TABLE 31.

Thickness of the flower.

(Average value of 20 flowers in mm.)

| | At 4 p.m. of the day previous to blooming | At 7 a.m. of the blooming day | At 8 a.m. of the blooming day | At 9 a.m. of the blooming day | At blooming time | After closing |
|---|---|---|---|---|---|---|
| I | 2.00 | 1.98 | 2.03 | 2.14 | 2.22 | 2.03 |
| II | 2.16 | 2.17 | 2.22 | 2.21 | 2.32 | 2.06 |
| Average | 2.08 | 2.08 | 2.13 | 2.18 | 2.27 | 2.05 |

Now if we assume that the thickness of a lodicule enlarges by $x$, and that this increase is the same both inside and outside, the outside increase will be $\frac{x}{2}$; and since there are two lodicules, the flower will be forced to increase its thickness by $x$ $\left(\frac{x}{2}\times 2=x\right)$. The increase in the thickness of the lodicule was compared with that of the flower from the data shown in Table 28 and 31 respectively, the results of which are seen in Table 32.

TABLE 32.

Comparison between increase in thickness of the lodicule and of the flower.

| | Increase in thickness based on that at 4 p.m. on the day previous to blooming (mm). | | | |
|---|---|---|---|---|
| | 7.30 a.m. | 8.30 a.m. | 9.30 a.m. | At blooming time |
| Lodicule | 0.04 | 0.06 | 0.09 | 0.19 |
| | 7.00 a.m. | 8.00 a.m. | 9.00 a.m. | At blooming time |
| Flower | 0.00 | 0.05 | 0.10 | 0.19 |

As the measurements were made on different days and at different times of the day, it is not proper to compare both figures directly; but since the increase shows a similar tendency in numerical value, the increase in thickness of the flower is considered to be closely related to that of the lodicule.

According to NAKAO (1911) the sudden swelling of the succulent tissue which occupies the inside of the hook-shaped part of the lemma, helps to separate the hooking. The author, however, regrets to say that he was unable to carry out investigations on this point.

### (2) Opening of the glumes

As already described, the lodicules swell suddenly at blooming time. The width of the lodicule which was about 1.04 mm at 9.30 a.m. became 1.20 mm at time of blooming (Table 28): it increased suddenly by the ratio of 1: 1.15. The swelling in the width is one-sidedly conspicuous (Fig. 8); and owing to this the lemma is pressed down at its base when it is opened. Although the hooking of both glumes is separated by the gradual increase of the lodicule's size, it is reasonable to suggest that the sudden increase in the thickness at blooming time completes the separation and makes it easier to open.

The angle between the glumes reaches its maximum about 20 minutes after the glumes begin to open. According to the author's observations, the angle at that time reaches 25–36.5 degrees, the average falling, practically speaking, between 31 and 32 degrees. The width of opening of the glumes is variable according to environmental conditions. For instance, the author found in the same day's observations that the angle between the glumes was 33.5 degrees in a plant inside the house; outside, the angles showed 32.4 degrees at the place not exposed to direct rays of the sun and 29.1 degrees under the direct exposure to sunshine. In the case where the plants were transferred from the outside to the inside of the house at 7, 8 and 9 a.m., the angles of opening in hastened blooming flowers were 31.2, 31.2 and 32.0 degrees respectively.

As mentioned above, the angle between the glumes reaches its maximum about at 20 minutes after the opening, and then gradually decreases again. It was already made clear by NAKAO (1911) and AKEMINE (1914) that the closing of the glumes is due to the elasticity of the base of lemma. It has been generally observed that the time required for closing is longer than that for opening. The length of time from the beginning of opening to the complete closing of the glumes is shown in Table 33.

TABLE 33.

Length of time from beginning of opening to complete closing of the glumes.

(Averaged for 10 flowers in minutes.)

| | rtificially hastened blooming | | Natural blooming | | |
|---|---|---|---|---|---|
| | Transferred from outside to inside the house at 8 a.m. | Transferred from outside to inside the house at 9 a.m. | Under direct sunshine | In the shade outside the house | Inside the house |
| I (June 13) | 84 | 85 | 75 | 81 | 78 |
| II (June 14) | 78 | 87 | 69 | 60 | 67 |
| Average | 81 | 86 | 72 | 71 | 73 |

According to the above table, the time required to remain open in natural blooming is practically the same in the three plots, but in the case where the blooming is hastened artificially, the time is somewhat longer.

### 3. *Relation between the elongation of filament and the blooming*

As has already been made clear, while the blooming or the opening of the glumes is not necessarily accompanied by the dehiscing of the anther, on the other hand the occurrence of elongation of filament following the opening is always observable. The filament gradually elongates before blooming, and immediately before blooming an end of the anther reaches the top of the glumes. As soon as both glumes open the filament rapidly elongates itself and throws the anther outside the glumes. The length of filament in blooming flowers is shown in Table 34.

TABLE 34.

Length of filament.

(Averaged for 10 flowers in mm.)

| At 4 p.m. of the day previous to blooming | At 7 a.m. on the day of blooming | Artificially hastened blooming (Transferred from outside to inside the house at 9 a.m.) | | | Natural blooming | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Under direct sunshine | | | Inside the house | | |
| | | Blooming begins | 20 minutes later | Closed | Blooming begins | 20 minutes later | Closed | Blooming begins | 20 minutes later | Closed |
| 2.5 | 3.3 | 5.1 | 6.2 | 7.4 | 5.5 | 7.0 | 8.2 | 5.4 | 6.9 | 8.3 |

Observing the flowers blooming inside the house, it was found that the elongated filament begins to droop after about 10 to 20 minutes. From the above table it is seen that the filament still continues to elongate to a certain extent after it begins to droop, and the length of the fully elongated filament is somewhat shorter in the case of artificially hastened than in that of natural blooming.

According to KADAM and PATIL (1933), the pressure exerted by the anther helps on the opening of the glumes. In other words, by the elongation of the filament the anthers press the glumes from the inside, causing them to open more easily. To ascertain whether it is actually the case or not, the author carried out the following experiment.

## MATERIAL AND METHOD

The material used was Taichu No. 65. In the afternoon of the day previous to the experiment, flowers that were expected to bloom on the following morning were chosen as materials, all the rest being cut off, and were arranged in the following three plots.

A. Anthers were removed: In removing the anthers, the author clipped the upper part of the lemma obliquely so as not to touch the hooking part of the glumes and then picked out the anther.

B. Control I: Glumes clipped by the same method as A, but the anthers were unremoved.

C. Control II: Normal.

The author thus compared the number of flowers opened.

## RESULTS OF THE EXPERIMENT

The results of the experiment are given in Table 35.

TABLE 35.

Relation between presence or absence of the anthers and opening of the glumes.

| | I (June 7) | | II (June 8) | | III (June 9) | | Total | | |
|---|---|---|---|---|---|---|---|---|---|
| | Number of flowers supplied | Number of flowers opened | Number of flowers supplied | Number of flowers opened | Number of flowers supplied | Number of flowers opened | Number of flowers supplied | Number of flowers opened | Percentage of flowers opened |
| A (Anthers removed) | 10 | 4 | 20 | 18 | 10 | 8 | 40 | 30 | 75.0 |
| B (Control I) | 10 | 4 | 20 | 10 | 10 | 6 | 40 | 20 | 50.0 |
| C (Control II) | 10 | 10 | 20 | 20 | 10 | 10 | 40 | 40 | 100.0 |

According to Table 35, in plot A (no anther) the number of open flowers was 75.0 per cent. It became clear from this that the existence of the anther is not an absolutely necessary condition for the opening of the glumes. Although not absolutely necessary, it is still questionable whether the anthers play any role for the opening of the glumes or not. From the fact that the number of open flowers in plot B (with anthers) was less than that in plot A (without anthers), however, the author cannot but conclude that the opinion of KADAM and PATIL is not to be accepted as true.

While in plot C all the flowers supplied opened, the number of the opened flowers in plot A and B was small. This seems probably due to the mechanical injuries caused by clipping off a part of glume. In spite of the fact that such injuries are considerably greater in plot A than in plot B, the number of the open flowers in plot A, however, were much greater than those in plot B. The reason for this is not clear.

As conclusion, the opinion that the anther helps the glumes to open by pressing them from the inside can not be accepted according to the data available so far as the author's investigations are concerned.

## V. APPLICATION OF ARTIFICIAL BLOOMING WITH INDEHISCENT ANTHERS TO CROSSING TECHNIQUE

In crossing technique, first the emasculation of the mother flowers must be carried out. The method of emasculation generally employed in rice flowers is to clip off about one third of the glumes in the early morning or on the previous afternoon and then to pick off the anthers with a pair of fine forceps. But this method presents some inconveniences as regards the success of the crossing. For instance, it is difficult to answer with certainty for the maturity of the flower and the floral organs are liable to get dry or to mechanical injury, because of clipping off a part of glumes. Hence the percentage of seed set in rice hybridization is relatively small, about 60% in in general, in spite of no special difficulties of the technique in itself. Moreover the rice kernels obtained in this way are usually small and abnormal in shape as illustrated by KATAYAMA (1933) and KAMO (1938-a), and further, as JONES (1929) already has pointed out, liable to insect injury because the upper portion of the kernels is exposed.

According to AKEMINE's (1909) investigations, while a common rice grain weighs over 20 mg in average, the hybrid one weighs only 18 mg and is

markedly longer than the ordinary one and it's upper end is pointed. Wishing to see how the degree of clipping of the glumes influences the shape and size of the grain, the author pursued three methods of clipping, namely, respectively clipping off one half, one fourth of both glumes and the upper portion of the lemma obliquely. The results were as follows:

TABLE 36.

Relation between the degree of clipping of the glumes and the size of rice kernel.

| | Clipped $\frac{1}{2}$ | Clipped $\frac{1}{4}$ | Clipped upper portion of lemma obliquely | Control |
|---|---|---|---|---|
| Length (mm) | 5.35 | 5.84 | 5.53 | 5.11 |
| Width (mm) | 2.17 | 2.58 | 2.59 | 3.02 |
| Thickness (mm) | 1.89 | 2.09 | 2.07 | 2.14 |
| Weight (mg) | 12.35 | 19.31 | 19.60 | 21.98 |

Note: Each 50-60 grains averaged. Taichu No. 65.

As shown in the above table, clipping of the glumes in any way causes kernels to increase in length but decrease in width and weight especially when the glumes are clipped to a considerable extent. For crossing purposes, it is recommended by JONES (1929), KONO (1934), YAMAMOTO (1935) and NAGAO (1936), to clip off the upper part of the glumes obliquely so as to save the palet as far as possible. Even by this method it is still inevitable to obtain the shriveled or poorly developed seeds. It is easily understood that such hybrid seeds will be nothing like so good in the coming germination and $F_1$ development as ordinary seeds, and in practice we usually meet with this fact. Therefore emasculation without clipping of the glumes is very desirable for crossing purposes.

Regarding a crossing technique in which emasculation is done without clipping, some reports has already been published. SHARNGAPANI (1924) recommended the following method: At the latest 2 hours before the flower opens, the two glumes are very gently pulled apart with the fingers and the anthers removed with a pair of fine bent forceps. About two hours later when the father plants begin to bloom, the emasculated flowers are pollinated and the glumes tied with a piece of fine silken thread to shut them. In this method, however, the process is excessively slow and the tying of each small flower with a silk thread is a troublesome work besides very often injuring the

lemma and palet as pointed out by CHAO (1928). TORRES (1927) and MULIMBAYAN (1935) also preferred the clip method to the split method. BHIDE (1925) recognized the injurious effect of artificial opening of the glumes and stated that a few flowers which open naturally with indehiscent anthers should be used for emascultaion. POGGENDORFF (1933) also used this method. PARNELL and others (1917) observed that in most cases dehiscence does not take place until the glumes are well open and the anthers are partially extruded. Therefore according to them it is possible to remove anthers, for crossing purposes, without clipping the glumes. The author also sometimes observed that in natural blooming indehiscence frequently occurs till the glumes are well open, but it is very difficult and unpracticable to find such flowers for crossing purposes at Taihoku.

According to RAMIAH (1927), blooming takes place without dehiscence of anthers if the rice panicle is covered with a black or brown paper bag about 1–1½ hours before the ordinary blooming time, so that the flower is readily emasculated and pollinated at the time when the father plant begins to bloom. JODON (1938) discovered a method of emasculation which is quite different from those mentioned above. He soaked the panicle in warm water (40°–44°C.) for about 10 minutes and succeeded in killing the pollen without injuring the pistil as well as the other floral organs. In this method the removing of the anthers is quite unnecessary.

The author also has thought out a new method which will be illustrated in this chapter. The method is based on the facts that the indehiscence of anthers usually occurs in the hastened blooming flowers. Although the author reported previously (KAMO 1938-a, b) on this emasculation method, he will again deal with it in detail.

### 1. *Method of emasculation*

First the mother plant previously transplanted from paddy to pot is placed outside of the house. When the pot is transferred into the crossing room 2-3 hours before natural blooming time, soon (generally after several minutes) the flowers begin to bloom and the anthers extrude without dehiscence, so that the anthers can be easily removed by picking off the filaments with a pair of fine forceps. The emasculation treatment therefore is very easy and hardly injures the other floral organs. Furthermore, pollen shedding which results from the artificial bursting of the anthers can be avoided because the forceps do not directly touch the anthers.

As clear from Chapter II, the environmental factor which hastens the blooming in this case is a sudden decline of light intensity, and the room in which the pot is transferred requires no special darkness. In a common house, the blooming is effectively hastened even when the windows are kept open.

In practice the time of transference of the pot is the most important factor. If it is too early the hastening will not occur, and as the time gets later the number of hastened blooms increases; but if too late, the flower can not be supplied for crossing purposes because the anthers will dehisce simultaneously with the opening of the glumes. Moreover, in the flower which blooms late, there is danger of the anthers dehiscing simultaneously with the blooming, even if the time of the transference is the usual one. According to the author's experience, emasculation was successfully carried out on the flowers which were transferred between 7 and 8 a.m. for the first crop* and between 8 and 9 a.m. for the second crop** and that bloomed within one hour. We cannot, however, determine with certainty the exact transferring time, because the time may vary according to environmental conditions or varieties, so that in practice, we must alter the time of transference accordingly. For instance, in a day when the temperature is high or in the case where the material is placed in the sunshine the time of transference should be earlier than when that is not the case.

### 2. *Emasculation by the new method and self-fertilization*

According to the author's method, emasculation is performed after the glumes have opened, so that it is quite natural to have some fear that self-pollination may occur simultaneously with the blooming. To ascertain this, the author emasculated a number of flowers both according to the new and to the ordinary clip method, and afterwards examined the percentages of self-fertilized flowers. The results were as follows:

---

* Cultivated between January and July: the blooming generally occurs in the later part of May and in the earlier part of June.

** Cultivated between July and November: the blooming generally occurs in the later part of September and in the earlier part of October.

TABLE 37.

Percentage of self-fertilization in emasculated flowers.

| Method of emasculation | Number of emasculated flowers | Number of self-fertilized flowers | Percentage of self-fertilization |
|---|---|---|---|
| New method | 427 | 12 | 2.8 |
| Clip method | 139 | 13 | 9.4 |

Notes: New method—Between 7-8 a.m. pots were transferred from outside to inside the house and the flowers which bloomed before 9 a.m. were emasculated. 28 varieties supplied.
Clip method—Between 4.00-5.30 p.m. of the day previous to blooming, about one third of the glumes were clipped off and emasculated. 10 varieties supplied.

According to the above table, it will be concluded that the new method presents no fear of self-fertilization as compared with the ordinary clip method. In this experiment the anthers were removed and the stigmas were not inspected in each case. For crossing purpose it will be possible to remove the self-pollinated flowers if the stigmas are carefully inspected with lupe.

### 3. *Results of crossing by the new emasculation method*

Although the percentage of seeds set in rice crossing varies considerably according to varieties and environmental conditions, it is generally about 60% in the ordinary clip method.

According to the author's method, the flower to be used for crossing purposes is at a rational stage of maturation and the trouble caused by drying of the floral organs is avoidable, and furthermore the mechanical injuries are reduced. Therefore, in this method not only the percentage of seeds set is higher but also the grains develop well, because they are fully protected by the glumes. From these facts it is possible to say that the hybrid seeds obtained by this method will show good results in germination and $F_1$ development. Table 38 shows the practical results of crossings performed by the author in 1936 and 1937. From this table the difference in the results between the two methods can easily be discovered, though in a strict sense it is not correct to compare the two methods with one another by means of these results, for these results are based on different combinations of varieties and dates of

TABLE 38.

Number of hybrid seeds obtained and from which developed $F_1$ plants and their percentage in 1936 and 1937.

| | Period of crossing | Number of flowers crossed | Number of seeds set | Number of $F_1$ plants developed | Percentage of seeds set | Percentage of developed $F_1$ plants to the number of seeds obtained | Percentage of developed $F_1$ plants to the number of flowers crossed |
|---|---|---|---|---|---|---|---|
| New method | 1936 1st crop | 291 | 247 | 183 | 84.9 | 74.1 | 62.9 |
| | 1936 2nd crop | 797 | 608 | 560 | 76.3 | 92.1 | 70.3 |
| | 1937 2nd crop | 432 | 389 | 216 | 90.0 | 55.5 | 50.0 |
| | Total | 1520 | 1244 | 959 | 81.8 | 77.1 | 63.1 |
| Clip method | 1936 1st crop | 404 | 221 | 102 | 54.7 | 46.2 | 25.2 |
| | 1936 2nd crop | 199 | 132 | 105 | 66.3 | 79.5 | 52.8 |
| | 1937 2nd crop | 310 | 198 | 37 | 63.9 | 18.7 | 11.9 |
| | Total | 913 | 551 | 244 | 60.4 | 44.3 | 26.7 |

crossing. The results obtained by means of the new emasculation method show, throughout the three crop seasons, 81.8% for seeds set and 63.1% for well developed $F_1$ plants to the total number of flowers crossed, while in the case of the ordinary clip method the percentage for seeds set and for developed $F_1$ plants are 60.4% and 26.7% respectively, thus there the remarkable difference especially in the percentages of developed $F_1$ plants are clearly shown. Hybrid seeds in the second crop of 1937 in general were very poor in germination and subsequent development owing to the low temperature after sowing, and the influence of bad weather conditions was specially noticeable in seeds crossed by means of the clip method.

It may possibly be pointed out that there are certain defects in the author's new method. The first is that the pollination is not easier than by the clip method, for in the latter the partially clipped glumes catch the pollen grains introduced and hold them well. However, the glumes generally keep open for about 1-1½ hours so that during this period the pollination is very easily undertaken and even if the glumes have closed it is not difficult to open them and pollinate, for the glumes do not hook unless the fertilization has been completed, as AKEMINE (1914) has already proved. Secondly the author's method may meet with difficulties because blooming is influenced by environmental

conditions, consequently resulting in a fluctuation of the hastening of blooming in the different varieties. According to the author's experience, however, these troubles are comparatively small as regards practical crossing. Moreover, in the new method the crossing work will not make satisfactory progress because the blooming process permits of the emasculation only during one or two hours in the morning. According to the author's experiments, however, in the second crop of 1936 160 panicles (five flowers per panicle) can be crossed in 22 days and the largest number being 16 panicles a day. Therefore, there is no inconveniences except in the case where a large number of crossings must be undertaken during a short period.

### 4. *The new emasculation method and the preservation of conceptive potency of the stigma*

NOGUCHI and HAMADA (1927) stated that the conceptive potency of the rice stigma persisted for about 5 days after maturation of the pistils, but that after 3 days it was greatly reduced and set seeds only 3.3%. KATAYAMA (1933) said that the period of conceptive potency lasted generally 4 days. In his experiments, seeds were produced for 52.5%, when pollinated on the third day after emasculation, and only 2.5% on the fourth day. According to the investigations made by NAGAO and TAKANO (1938), the percentage of seeds set was 20.3% when pollinated on the third day after emasculation, and after 5 days little conceptive potency was seen.

According to the author's experiment carried out by means of the new emasculation method, the percentage of seeds set was 71.4% when pollinated on the third day after blooming (emasculation) and even after five days a fair percentage of seeds set was obtained. The results are as follows:

TABLE 39.

Number of days from blooming to pollination and percentage of seeds set.

| Number of days from blooming (emasculation) to pollination | Number of flowers pollinated | Number of seeds set | Percentage of seeds set |
|---|---|---|---|
| 1 | 24 | 23 | 95.8 |
| 2 | 33 | 28 | 84.8 |
| 3 | 21 | 15 | 71.4 |
| 4 | 19 | 7 | 36.8 |
| 5 | 19 | 9 | 47.4 |
| 6 | 7 | 0 | 0.0 |
| 7 | 10 | 0 | 0.0 |

It is obvious that in the author's experiment the preservation of conceptive potency of the rice stigma is longer than in those of previous investigators. This must be due to the protective influence exerted by the complete glumes.

From the above result it is considered that at least for 3 days after the blooming (emasculation) the flowers may be used for crossing purposes if the emasculation is performed by means of the author's method.

## VI. DISCUSSION

It is a well known fact studied by KÖRNICKE and TSCHERMAK that in rye the mechanical stimulation causes the blooming of flowers (cited from FRUWIRTH 1923-a). NAKAO (1911) also ascertained this fact.

As regards the blooming phenomenon due to stimulation in rice flowers there are not many reports so far as the author is aware. NAKAO (1911) reported that in rice shaking of the panicles did not cause blooming. According to AKEMINE's (1914) experiment, even the heavy shock given to the panicles did not cause blooming; from this fact he concluded that a storm would have no influence upon the blooming of rice flowers. NOGUCHI (1927-b) stated that the shaking by rain and wind may act as a mechanical agency to produce blooming, so that the total number of blooming flowers may not decrease even when environmental conditions are bad, but retard the blooming time in that day. On the contrary, POGGENDORFF (1932) stated that wind and cloud, if slight, have the effect of postponing blooming, and if marked, they prevent the blooming entirely while rain has a more noticeable effect.

From the opinions above mentioned and the author's experimental results it is considered that in rice the shaking which is given to the panicles has no stimulating action in hastening the blooming, unlike what is the case with rye.

On the other hand, however, the author found out that certain artificial treatments induced blooming 2-3 hours before the normal blooming time, i.e., sudden decline of light intensity, unusually high temperature or rubbing of the panicle, each acting as direct stimulating agencies inducing the blooming. The author also discovered that in this case hastened blooming was always accompanied by indehiscence of the anthers, provided the hastening was noteworthy. RAMIAH (1927) testified to the fact that blooming with closed anthers may take place if the panicle is covered with a black or brown paper

bag 1–1½ hours before the natural time of blooming. According to him such hastening of blooming is due to the high temperature around the flowers which is raised by absorbing solar heat because the bag is black: the inside temperature of the bag is recorded as 28°–30°C. which is higher than the outside by 4°–5°C. In accordance with the author's experimental results, however, the hastened blooming with indehiscent anthers which RAMIAH found was presumably the result of interception or decline of light intensity due to the black or brown colour of the paper bag, rather than the result of the high temperature. In any case RAMIAH's view that "the factors governing flower-opening being different from those concerned in the dehiscence of the anthers" is reasonable.

As regards the blooming time of rice flowers during the day, the results of observations made by many investigators are not always in agreement. For instance, according to AKEMINE's (1914) observations made in Sapporo, blooming usually begins at about 9 a.m., in a flush between 11 a.m. and noon, and ceases at about 3 p.m.; Iso (1928) observed that in Taihoku blooming began at about 9 a.m., reached the maximum between 11 a.m. and noon, and ceased at about 2 p.m. in the case of the first crop. In the Philippines, TORRES (1923) observed that the flowers usually opened between 9 and 11.30 a.m. on a bright sunny day. According to THOMPSTONE (1915), in Burma the blooming occurs usually between 7 and 10 a.m., and will reach its maximum at about 8–9 a.m. HECTOR (1913) states that in the case of Aus varieties, which in Lower Bengal bloom during the months of May and June, the opening of the glumes begins usually between 7 and 8 a.m. and continues until about 10 a.m. when it stops for the day, but in the case of the Aman varieties, which generally begin to bloom in late October or early November, not till later in the afternoon, beginning usually between 9 and 10 a.m. and continuing until midday. In the Bombay Presidency, KADAM and PATIL (1933) said that no flowers were observed to bloom before 10 a.m. or after 2 p.m. The maximum blooming was between 11 a.m. and noon. v. d. STOK (cited from FRUWIRTH 1923-b) observed that in Java blooming mostly occurred between 9 a.m. and 1 p.m., and in a flush between 10 a.m. and noon. Further, JONES (1924) reported that in California blooming takes place mainly between noon and 2 p.m. LAUDE and STANSEL (1927) found out that in Texas no blooming occurred before 8 a.m. and none after 4 p.m., the maximum number blooming between 11 a.m. and noon.

The times of blooming during the day are thus not always in agreement with one another for the following possible reasons:

(1) disagreement between local and solar time,

(2) varietal difference, and

(3) difference in environmental conditions.

The author will now study these points in detail.

(1) A certain time for a district is not the same in the essential meaning according to the sun when compared with that in other district of different longitude, if the same standard time is adopted. Therefore, the time during the day at which blooming phenomenon would occur, will differ according to the longitude, if the same standard time is adopted, because the biological phenomenon would not be influenced by artificially designated time.

(2) HARAJIMA (1936) threw some light on the difference between upland and lowland rice varieties in respect of time of blooming. According to him the percentage of upland and lowland rice flowers which bloomed before 10 a.m. was 29% and 3% respectively, and that of the flowers which bloomed in the afternoon was 4% and 33% respectively in relation to the total number of flowers which bloomed during the day, while the intensive flush was recorded between 10 and 11 a.m. in the upland and between 11 a.m. and noon in the lowland varieties. In accordance with the observations made by THADANI and DURGA DUTT (1928), thirteen varieties which bloomed between September 8th and October 7th all began blooming at 7.30 a.m., six varieties blooming between October 8th and 23rd did not begin to bloom before 8.30 a.m., and the four late types blooming between October 29th and November 9th, only began to open their flowers at 9.30 a.m. He also confirmed that this difference was not purely a matter of temperature, as the opening of flowers began at a different temperature in the different varieties. Also SANTOS (1933) and ADAIR (1934) observed that the blooming time was not always the same for each variety. In wild rice, there are species showing more marked differences as regards blooming time during the day. RAMIAH (1927) discovered that the wild rice *Oryza latifolia* bloomed between 5 and 7 a.m., while similarly the wild rice *O. longistaminata* bloomed between noon and 2 p.m. The author also usually recognizes varietal differences as regards blooming time during the day.

(3) That the blooming time of rice flowers during the day is influenced by environmental conditions, is borne out by every investigator who has occupied himself with this problem. Among environmental factors, those which are most closely related to blooming time are temperature and light.

According to AKEMINE's (1914) observations, blooming time in a day of high temperature is generally early in the morning and in a day of low temperature it is late, and in extreme cases of low temperature it even extends until night. ADAIR (1934) also observed that blooming time in a day of high temperature is earlier than in one of low temperature. According to TSUJIKAWA (1915), blooming may began as late as noon or 2 p.m. when the temperature is low, and NOGUCHI (1927-a) as well as Bhide and BHALERAO (1927) also said that a low temperature retards the blooming. That the light is not an absolutely necessary factor for the opening of the rice glumes, has already been made clear by AKEMINE (1914), TSUJIKAWA (1915) and NOGUCHI (1926), and the author has also confirmed this fact. The light, however, is not of indifference to the opening of the rice glumes. NAKAO (1911) observed that the rice plant set in a cellar bloomed more abundantly on the one side whence the light came than on the other. NOGUCHI (1926) has artificially retarded the blooming by light interception; moreover he observed that the flowers bloomed under electric light during the night. Further, the author's experiments show that if the time of exposure to the morning light is retarded, the blooming time is also retarded and that electric lighting from the previous night hastens the blooming. These facts are all to be considered as indicating that the light has an active influence on the blooming of rice flowers during the day. MITRA and GANGULI (1932), POGGENDORFF (1932), KADAM and PATIL (1933) all observed that in bright weather the blooming processes were hastened, whereas cloudy or rainy weather retarded them considerably. TORRES (1923) stated that the rice flowers open up after several hours of exposure to sunlight. Either ADAIR (1934) or RAMIAH (1927) assumed that the sunlight combined with the temperature, would play an important part in the opening of the glumes. Furthermore, SHARNGAPANI (1924) and SETHI and SAXENA (1930) observed that the sunshine hastened the blooming process and cloud and rain retarded it. According to Iso (1928) the blooming time in the first crop is generally earlier than that in the second crop, and the author also observed this fact. Though this difference would be due to some extent to the influence of the temperature, but the sunlight is supposed to be also an important cause, since in the first crop period the time of sunrise is earlier than in the second crop in Taihoku (there is about 40 minutes difference). Environmental conditions will not be identical in every district and season, so that as a matter of course some differences will be found as to blooming time in different districts.

Although not always in agreement, still it may be said that the blooming time of rice flowers in the day thus tends to concentrate about a certain time, generally between 10 a.m. and noon. In other cereal plants, however, there are marked difference in the blooming time during the day according to the species. According to the results of the observations made by FRUWIRTH (1923-a), LEIGHTY and SANDO (1924), MINAMI and MISONOO (1933) and YAMAGUCHI (1935), in wheat, barley and rye blooming occurs not only in the daytime but also extends on into the night and the blooming distribution during the day is wide, while in oats the blooming time is limited to several hours mostly between 2 and 3 p.m., and in millet the blooming occurs between 7.30 a.m. and 2 p.m., but mostly between 9 and 10 a.m. These differences in the blooming time during the day should be attributed to the characteristics of the species which respond to the environmental factors in different ways, thus raising what might be a very interesting problem.

It was already made clear by MISONOO (1936) that the blooming of oat flowers being limited to a certain period during the day is due to the indispensability of certain changes of temperature. As to the reason why the blooming of rice flowers does not occur until they reach a certain time of the day, as already mentioned, AKEMINE (1914) stated that they need to be in a temperature above a certain degrees for a set period of time; Iso (1913) presumed that periodic change of temperature might be necessary. According to the author's experiment, it is clear, as Iso presumed, that an intimate relation subsists between periodic change of temperature during the day and the time of blooming; and not only the periodic change of temperature but also the periodic change of light (alternation of day and night) have a close relation to the blooming time of the day. On the contrary, the influence of humidity on the blooming of rice flowers is considered not to be so marked as that of the temperature or light. Hence it may be concluded that the temperature and the light have a marked influence on the blooming of rice flowers and the blooming tends to gather about a certain time of the day in consequence of the periodic changes of temperature and light.

It is a well known fact that the blooming of gramineous plants occurs as a consequence of the swelling of the lodicules. SAKAMURA (1925) interpreted the phenomenon of blooming in rye flowers which is caused by mechanical stimulation as a turgor movement in the plant from the view point of mechanism, viz. "Seismonastie". On the day previous to blooming both glumes of the rice flower still tightly hook one other and it is difficult to

separate them. Firstly, therefore, the separation of the hooked glumes is necessary for the blooming. Though it is clear that the lodicules swell suddenly at the time of blooming and consequently the opening of the glumes occurs, this sudden swelling does not bring about the separation of the hooked glumes and the opening of them at the same time, but that the gradual increase in size of the lodicules first causes the unhooking before the blooming time is reached, and then the glumes are opened by the sudden swelling of the lodicules. Naturally the grades of development of the lodicules are not the same, depending on the flowers, so that the nearer the blooming period of the day approaches, the greater the increase in the number of unhooked flowers. Therefore the number of flowers the blooming of which can be hastened is expected to increases as the time of the hastening treatment is delayed. When the treatment be carried out at the proper time, a turgor movement of the lodicules will take place in response to the treatment and cause the opening of the glumes, but the anthers will not dehisce simultaneously, because the swelling of the lodicules and the dehiscence of the anthers have no direct relation to each other.

The angle formed by both glumes of the flower in bloom is of 28-36 degrees and for the most part, of about 30 degrees according to AKEMINE (1914). SUZUTA and TOMURA (1922) stated that the angle is usually of about 25 degrees and difference can be seen according to varieties. POGGENDORFF (1932) observed that the maximum angle was of about 30 degrees. This angle is not always the same, but varies according to environmental conditions. AKEMINE (1914) and TAKIGUCHI (1930) observed that the angle was small on days of low temperature. According to the author's observations, the minimum angle was of 25 degrees, the maximum of 36.5 degrees and in most cases of 31-32 degrees and a difference could be seen due to whether there was sunshine or not. It may be presumed that the angle of opening will depend upon the width of the swollen lodicules, though there are lacking concrete examples.

As regards the length of time during which the flowers remain open, the reports of many investigators are not in agreement. Iso (1913) observed that the flowers usually remained open for about 50 minutes, and AKEMINE (1914) said that under ordinary environmental conditions the time was $1\frac{1}{2}$–$2\frac{1}{2}$ hours, but low temperature and high humidity lengthened it. TSUJIKAWA (1915) stated that the time varied from 20 minutes to over 2 hours and generally about 1 hour. SUZUTA and TOMURA (1922) observed that the time averaged 32-38

minutes and when the temperature was high the time was short. TAKIGUCHI (1930) observed that it was usually 1–2 hours, while at 15°C. flowers remained open for several hours and occasionally for more than 1 day. To cite foreign examples, HECTOR (1913) gave 30 minutes or 1–1½ hours according to seasons, LAUDE and STANSEL (1927) gave 42–125 minutes, BHIDE and BHALERAO (1927) 55–60 minutes, THADANI and DURGA DUTT (1928) 32–70 minutes, SETHI and SAXENA (1930) 50–60 minutes, and POGGENDORFF (1932) gave 30–75 minutes and said that the time is governed by the relative humidity of the air. Furthermore, KADAM and PATIL (1933) said that the flower may remain fully open for 5–12 minutes in bright weather, while under cloudy or rainy conditions it may stay open as long as half an hour, and that the closing of the glumes may require 32–45 minutes in bright weather and 40–50 minutes on a cloudy day, whereas in rainy weather the closing activity may be so delayed as to require over an hour. It is uniformly recognized by many investigators that the length of time between the opening and the closing of the rice flower is relatively short under favourable conditions, and relatively long at a low temperature and high humidity, so it must be evident that environment has a marked influence upon the length of that time. According to the author's investigations, in all three plots, viz. under direct sunshine, in the shade outside the house and in the inside of the house, the time is about 1 hour and 10 minutes and there are few differences between them. This may be due to the fact that even though the temperature and the humidity of these three plots might not be the same, all had been within the optimum range, so that no marked difference between the times of remaining open resulted. On the contrary in the flowers the blooming of which has been hastened by transference from outside to inside the house, the time of remaining open seems to be a little longer. This may correspond to the results found by Iso (1928), i.e., that the flowers which bloomed late in the morning were likely to remain open for a shorter time as compared with those that bloomed early. This is perhaps due to the fact that early in the morning the temperature is still low and the humidity is high, while in the course of time the temperature rises and the humidity falls.

The closing of the glumes takes place regardless of the state of the anthers or whether the pollination is accomplished or not, as was made clear by AKEMINE (1914). Rice flowers which have been forced to open their glumes by fingers or forceps 2–3 hours before natural blooming time, lose their closing power for the most part, while flowers the blooming of which has been

hastened by artificial treatment, will close their glumes after a certain period of time without any trouble, as naturally blooming flowers.

Notwithstanding the factors governing the opening of rice flowers not being the same as those connected with the dehiscence of the anthers and, consequently, both phenomena being considered due to different physiological mechanisms respectively, the opening of the glumes is intimately related with the elongation of the filament, so that the opening is always followed by its rapid elongation. The blooming which takes place early in the morning by artificial means does not follow the dehiscence of the anther, but always follows the rapid elongation of the filament as in natural booming, which after keeping turgidity for a certain period droops gradually. In this case, however, the length of the fully elongated filament seems usually somewhat shorter than that in ordinary cases. Considering this fact, the swelling of the lodicule and the elongation of the filament is likely to be due to the same physiological mechanism. KADAM and PATIL (1933) said that the pressure exerted by the anthers is evidenced by the gradual separation of the glume apices, but the author could not satisfy himself of this fact and, according to his experiment, the glumes opened regardless of whether the anthers existed or not.

In the crossing of rice plants clipping off a portion of the glumes is usually employed as a means of emasculation. Clipping of the glumes, however, is likely to reduce the percentage of seeds set and the development of the grain and, accordingly, the percentage of well developed $F_1$ plants. To remove this disadvantages it is desirable to emasculate the flower without clipping the glumes. As regards the method adopted, several reports already exist such as those by SHARNGAPANI (1924), BHIDE (1925), RAMIAH (1927), POGGENDORFF (1933) and JODON (1938). According to the results of the author's experiments, rice flowers begin to bloom even 2–3 hours before natural blooming time and the anthers extrude without dehiscence, if the plant is transferred from outside to inside of the house. Therefore the anthers can be easily removed without clipping the glumes. The time of blooming and dehiscence of anthers, however, are intimately related to the environmental conditions and varieties. Therefore it can not be asserted whether the method which is successful in Taihoku would also be feasible in another district or not. The following instances clearly tell the facts, viz. RAMIAH's (1927) method, which gives rise to blooming with indehiscent anthers by covering the panicle with a black or brown paper bag was not successful

when tested by POGGENDORFF (1933) and JODON (1938), and the method recommended by BHIDE (1925) and POGGENDORFF (1933) of using the flower which has bloomed naturally without dehiscing of anthers, would have little promise of success under the environmental conditions obtaining in Taihoku.

The purpose of emasculation is to keep the stigma from self-fertilization, thus the removing of the anthers is not absolutely necessary for crossing. STEPHENS and QUINBY (1933), by hot water treatment and SUNESON (1937), by low temperature treatment, with sorghum and wheat head respectively, succeeded in killing pollen without injuring the other floral parts, and further, JODON (1938) when applying this method to the rice panicle discovered that treatment with hot water at about 40°–44°C. was most suitable for emasculating purpose. This method, however, requiring as it does that the water should be kept at optimum temperature, and which, if misapplied, may produce injurious effects on the female organs, or self-fertilization, in practice may be found to be accompanied by no less difficulties. For small grained cereals, however, such as sorghum, in which individual treatment of the flower is very difficult, it may be a useful method. But in species, such as rice, in which individual treatment of the flower is relatively easy, the method of removing anthers may be more suitable to ensure successful crossing. According to JODON's results, the percentage of seeds set in crosses by the hot water method is 73.2% as maximum and 35.7% for 3 years as an average. On the contrary the author's findings show 90.0% in the second crop of 1937 as a maximum and 81.8% as an average covering 3 crop seasons. Though it is not proper to compare the two methods with each other only on the evidence of the records mentioned above, because the percentage of seeds set may differ according to environmental conditions or varieties, it will be granted that the author's method is pertinent given the environmental contions in Taihoku.

## VII. SUMMARY

In 1935–38 the author was engaged in experimental studies on the blooming of rice flowers and he acquired some knowledges of the artificial hastening of blooming, of blooming in relation to environmental factors, of the physical mechanism of the opening of glumes and of the application of artificial blooming to crossing technique. These are summarized as follows:

## EXPERIMENTS ON THE ARTIFICIAL HASTENING OF BLOOMING IN RICE FLOWERS

1. In Taihoku, the natural blooming of the rice flowers generally begins about 9 a.m. Some of the flowers, however, can be made to bloom earlier by transferring the plant from the outside to inside the house when they begin to bloom even 2–3 hours before the natural blooming time.

2. The earliest time of transference which is fully effective for hastening the blooming may be different in different varieties or environmental conditions, but it is about 6 a.m. so far as the author's experiments showed.

3. The length of time between transference and the beginning of blooming is not always definite, but in many cases it is 3–10 minutes. There is a tendency showing that the later the plant is transferred the shorter this time is.

4. In the early transferred plants, the blooming process which has been hastened by the transference does not continue for long, the remaining flowers suspending their opening for some time until ordinary blooming period, and then occurring again, thus presenting the "second blooming". When the transference is made so early, the opening of only a few flowers is hastened and many flowers remain until the second blooming; the later the plants are transferred, the greater the number of flowers the blooming of which is hastened, and in the plants transferred at 10 a.m., it is difficult to discover a clue indicating whether the blooming was hastened or not and in this case the blooming occurs only immediately after the transference, almost of all the flowers opening within about an hour.

5. The difference of temperature between the outside and the inside of the house is not the cause of the hastening of blooming.

6. The difference of humidity between the outside and the inside of the house also does not provide the cause for the hastening of blooming.

7. Sudden decline of light intensity hastens the blooming. That is, the blooming is hastened if the light is weakened by spreading a black cloth over the plant. The number of flowers the blooming of which is hastened varies according to the time of treatment, and the greater the degree of weakening, the more effective the treatment. From the above it is considered that hastening of blooming which occurs after transference from outside to inside the house is due to the weaker intensity of light inside the house as compared with that outside.

8. Hastening of blooming which occurs after transference from the out-

side to the inside of the house, is more marked in flowers which received direct sunshine from the early morning than in those which did not. From this fact it is not difficult to assume that the hastening would be considerably varied by w ather conditions.

9. Treatment by high temperature for a short time, also hastens blooming. In the panicle which was kept at 40°C. for 20 seconds, a few flowers bloomed as early as about 7 a.m. At 50°C. it was more marked, and at 35°C. no effect was seen.

10. Shaking the panicle has no effect upon hastening of the blooming, but by rubbing the panicle blooming occurred as early as about 6 a.m.

11. While blooming is generally followed by simultaneous dehiscence of the anther, the condition is markedly different in artificially hastened blooming. That is, when the hastening treatment is performed relatively late, bloomin is soon followed by dehiscence of the anthers, but in the flowers the blooming of which occurred early through treatment, the anther will droop without dehiscence. Such flowers rarely fertilize themselves, even though the anther is not removed.

## EXPERIMENTAL STUDIES ON SOME ENVIRONMENTAL FACTORS AFFECTING THE NATURAL BLOCMING TIME OF RICE FLOWERS

1. The light is not an absolutely necessary factor for the blooming of rice flowers, but plays an important role affecting the blooming time of the day.

2. In days where periodic changes of temperature were slight, the blooming took place successively through the day and the night in the plot lighted continuously and in the plot darkened in the daytime and lighted at night the blooming mostly occurred between 6 p.m. and 2 a.m.

3. If the time of exposure to the morning light is retarded, the blooming time is also retarded.

4. If lighted during the previous night, the blooming begins earlier than the normal blooming time.

5. There is an intimate relation between periodic changes of temperature during the day and blooming time. Namely, the blooming occurs in a flush when a periodic rising temperature approaches its maximum, but this blooming time can be modified by light conditions.

6. The variations in humidity have no marked influence upon the blooming time.

## PHYSICAL MECHANISM OF THE OPENING OF RICE FLOWERS

1. It is clear that the opening of rice flowers is caused by the swelling of the lodicules. According to the author's investigations the width and the thickness of the lodicule was 0.9 mm and 0.39 mm respectively on the evening previous to blooming, and then gradually increased reaching 1.04 mm and 0.48 mm respectively at about an hour before blooming time. At blooming time it swelled suddenly reaching 1.2 mm in width and 0.58 mm in thickness. No marked variation in length, however, was observed.

2. In general two glumes of the rice flower, on the day previous to blooming, are firmly hooked together and it is difficult to open them. Accordingly, unhooking of the glumes is first necessary before the flower can bloom. The agent which causes the unhooking is chiefly the gradual increase in thickness and width of the lodicule before the blooming time, and the nearer the blooming period of the day approaches the more the number of unhooked flowers increases.

3. The gradual increase in thickness of the lodicule naturally pushes the lemma outwards, and consequently the flower gradually increases in thickness as the blooming time approaches. The thickness of the flower which was 2.08 mm in the evening of the day previous to blooming, became 2.18 mm about an hour before blooming time and reached 2.27 mm at blooming time.

4. After being unhooked, the glumes are opened by the sudden swelling of the lodicules, chiefly owing to their increase in width. The increase in the width is conspicuous in a down-outward direction.

5. The angle between the glumes reaches its maximum about 20 minutes after the glumes begin to open. In general the angle is of about 31–32 degrees, though it may not always be the same according to difference of environmental conditions.

6. The length of time between the beginning of opening and the complete closing of the glumes was generally found to be about 1 hour and 10 minutes.

7. The assumption that the anther helps glumes to open by pressing upon them from the inside has not been proved. The glumes could open regardless of whether the anthers existed or not.

## APPLICATION OF ARTIFICIAL BLOOMING WITH INDEHISCENT ANTHERS TO CROSSING TECHNIQUE

1. The method of emasculation generally employed in rice flowers is to clip off about one third of the glumes and then to pick off the anthers. As the result of glume clipping, however, the flowers are liable to mechanical injury or to cause drying of the inner organs. Consequently the percentage of seeds set in rice hybridization is relatively small, generally about 60%, in spite of no special difficulties in the technique itself. Moreover the grains obtained in this way are usually small and abnormal in shape; it will also be easily understood that such hybrid seeds will be nothing like so good in the coming germination and $F_1$ development as ordinary seeds.

2. The author succeeded in emasculating rice flowers very easily without clipping the glumes by utilizing as follows the peculiar habit of their blooming. First the mother plant previously transplanted from paddy to pot is placed outside of the house. When the pot is transferred into the crossing room (the room is required to be somewhat darker than outside of the house) 2–3 hours before the natural blooming time, the flowers soon (generally after several minutes) begin to bloom and the anthers extrude without dehiscence, so that the anthers can easily be removed by picking the filaments with a pair of fine forceps.

3. According to the author's method, the flower to be used for crossing purposes is at a rational stage of maturation and the trouble caused by drying of the floral organs is avoidable, and furthermore the mechanical injuries are reduced. Therefore, in this method the percentage of seeds set is very good, generally about 80%.

4. The hybrid seeds obtained by this method are well developed, for they are fully protected by the glumes. As a matter of course they show good results in germination and $F_1$ development. By this method the percentage of developed $F_1$ plants to the number of seeds obtained, was 77.1%, while by the ordinary clip method it was 44.3%.

5. In flowers emasculated by the author's method, the preservation of conceptive potency of the rice stigma was longer than in those of previous investigators. Namely, the percentage of seeds set was 71.4% when pollinated on the third day after blooming, and 47.4% even on the fifth day.

## VIII. LITERATURE CITED


1. ADAIR, C. R. 1934: Studies on blooming in rice. Jour. Amer. Soc. Agron. Vol. **26**, 965.
2. AKEMINE, M. 909: Studies on the blooming and crossing in rice. (Japanese) Jour. Sapporo Soc. Agric. Forest. No. 2/3, 42.
3. AKEMINE, M. 1914: Ueber das Blühen des Reises und einige sich daran anknüpfende Erscheinungen. Zs. Pflanzenzücht. Bd. **2**, 339.
4. ARBER, A. 1934: The Gramineae. Cambridge.
5. BHIDE, R. K. 1925: Our experience in crossing different varieties of rice at Karjat. Agric. Jour. India Vol. **20**, 280.
6. BHIDE, R. K. and BHALERAO, S. G. 1927: The Kolamba rice of the North Konkan and its improvement by selection. Mem. Dep't. Agric. India, Bot. Series Vol. **14**, 199.
7. CHAO, L. F. 1928: The disturbing effect of the glutinous gene in rice on a Mendelian ratio. Genetics Vol. **13**, 191.
8. FRUWIRTH, C. 1923 a: Handbuch der landwirtschaftlichen Pflanzenzüchtung. Bd. **4**. Berlin.
9. FRUWIRTH, C. 1923 b: Handbuch der landwirtschaftlichen Pflanzenzüchtung. Bd. **5**. Berlin.
10. HARAJIMA, S. 1936: Comparative studies of upland and lowland rice varieties in regard to the time of blooming. (Japanese) Proceed. Crop Science Soc. Japan Vol. **8**, 527.
11. HECTOR, G. P. 1913: Notes on pollination and cross-fertilization in the common rice plant, *Oryza sativa* Linn. Mem. Dep't. Agric. India, Bot. Series Vol. **6**, 1.
12. IKENO, S. 1914: Ueber die Bestäubung und die Bastardierung von Reis. Zs. Pflanzenzücht. Bd. **2**, 495.
13. ISEDA, M. 1930: Studies on the influence of outside condition on the blooming of rice flowers. (Japanese) Graduation Thesis.
14. ISO, E. 1913: Observations on the time of blooming and pollination in rice. (Japanese) Formosan Agric. Review No. **80**, 3.
15. ISO, E. 1928: Studies on Formosan rice from the stand point of plant breeding. (Japanese) Rep. Dep't. Agric. Gov't. Research Institute Formosa No. **37**.
16. JODON, N. E. 1938: Experiments on artificial hybridization of rice. Jour. Amer. Soc. Agron. Vol. **30**, 294.
17. JONES, J. W. 1924: Observations on the time of blooming of rice flowers. Jour. Amer. Soc. Agron. Vol. **16**, 665.
18. JONES, J. W. 1929: Technic of rice hybridization in California. Jour. Amer. Soc. Agron. Vol. **21**, 35.
19. KADAM, B. S. and PATIL, G. G. 1933: Blooming and anthesis in Kolamba rice. Indian Jour. Agric. Science Vol. **3**, 577.
20. KAMO, I. 1938 a: A new method of emasculating rice flowers. (Japanese) Formosan Agric. Review No. **374**, 2.
21. KAMO, I. 1938 b: Application of artificial blooming in rice hybridization work and some experiments concerning it. (Japanese) Nogaku Ronso, p. 120. Tokyo.
22. KATAYAMA, Y. 1933: Crossing experiments in certain cereals with special reference to different compatibility between the reciprocal crosses. Mem. Coll. Agric. Kyoto Imp. Univ. No. **27**.

23. KNUTH, P. 1909: Handbook of flower pollination. Oxford.
24. KONO, H. 1934. Some notes on rice hybridization work. (Japanese) Agric. and Hortic. Vol. **9**, 2253.
25. LAUDE, H. H. and STANSEL, R. H. 1927: Time and rate of blooming in rice. Jour. Amer. Soc. Agron. Vol. **19**, 781.
26. LEIGHTY, E. and SANDO, W. J. 1924: The blooming of wheat flowers. Jour. Agric. Research Vol. **27**, 231.
27. MINAMI, Y. and MISONOO, G. 1933: Observations on the blooming of cereal plants. (Japanese) Rep. Farm Hokkaido Imp. Univ. No. **4**.
28. MISONOO, G. 1936: Ecological and physiological studies on the blooming of oat flowers. Jour. Fac. Agric. Hokkaido Imp. Univ. Vol. **37**, 211.
29. MITRA, S. K. and GANGULI, P. M. 1932: Studies in Surma Valley rices and their classification. Indian Jour. Agric. Science Vol. **2**, 571.
30. MULIMBAYAN, M. B. 1935: A comparative study of two methods of emasculating rice flowers for artificial hybridization work. Philippine Agriculturist Vol. **24**, 574.
31. NAGAO, S. 1936: Genetics and breeding in rice. (Japanese) Tokyo.
32. NAGAO, S. and TAKANO, T. 1938: On the duration of conceptive power in rice pollen and stigma. (Japanese) Nogaku Ronso, p. 88. Tokyo.
33. NAKANO, T. 1929: Influence of the outside condition on the blooming of rice flowers. (Japanese) Graduation Thesis.
34. NAKAO, S. 1911: On the mechanism of blooming of cereal plants. (Japanese) Jour. Sapporo Soc. Agric. Forest. No. **10**, 1.
35. NOGUCHI, Y. 1925: Ueber den Einfluss der Aussenbedingungen auf das Blütenöffnen der Reispflanzen. I. Feuchtigkeit. (Japanisch) Jour. Soc. Agric. Japan No. **274**, 239.
36. NOGUCHI, Y. 1926: Ueber den Einfluss der Aussenbedingungen auf das Blütenöffnen der Reispflanzen. II. Licht. (Japanisch) Jour. Soc. Agric. Japan No. **279**, 59.
37. NOGUCHI, Y. 1927 a: Ueber den Einfluss der Aussenbedingungen auf das Blütenöffnen der Reispflanzen. III. Temperatur. (Japanisch) Jour. Soc. Agric. Japan No. **290**, 20.
38. NOGUCHI, Y. 1927 b: Ueber den Einfluss der Aussenbedingungen auf das Blütenöffnen der Reispflanzen. IV. Regen und Regensturm. (Japanisch) Jour. Soc. Agric. Japan No. **293**, 177.
39. NOGUCHI, Y. 1927 c: Ueber den Einfluss der Aussenbedingungen auf das Blütenöffnen der Reispflanzen. V. Trockenheit. (Japanisch) Jour. Soc. Agric. Japan No. **301**, 568.
40. NOGUCHI, Y. 1929: Studien über den Einfluss der Aussenbedingungen auf das Aufblühen der Reispflanzen. Jap. Jour. Bot. Vol. **4**, 237.
41. NOGUCHI, Y. und HAMADA, S. 1927: Die Befruchtungsfähigkeit der Reispflanzen. (Japanisch) Jour. Soc. Agric. Japan No. **300**, 515.
42. PARNELL, F. R., RANGASWAMI AYYANGAR, G. N. and RAMIAH, K. 1917: The inheritance of characters in rice, I. Mem. Dep't. Agric. India, Bot. Series Vol. **9**, 75.
43. POGGENDORFF, W. 1932: Flowering, pollination, and natural crossing in rice. Agric. Gaz. New South Wales Vol. **43**, 898.
44. POGGENDORFF, W. 1933: Artificial hybridization of rice. Agric. Gaz. New South Wales Vol. **44**, 283.
45. RAMIAH, K. 1927: Artificial hybridization in rice. Agric. Jour. India Vol. **22**, 17.

46. SAKAMURA, T. 1925: Plant physiology. Lecture.
47. SANTOS, J. K. 1933: Morphology of the flower and mature grain of Philippine rice. Philippine Jour. Science Vol. **52**, 475.
48. SETHI, R. L. and SAXENA, B. P. 1930: Classification, and study of characters, of the cultivated rices in the United Provinces. Mem. Dep't. Agric. India, Bot. Series Vol. **18**, 149.
49. SHARNGAPANI, S. G. 1924: A few observations on paddy crossing. Agric. Jour. India Vol. **19**, 48.
50. STEPHENS, J. C. and QUINBY, J. R. 1933: Bulk emasculation of sorghum flowers. Jour. Amer. Soc. Agron. Vol. **25**, 233.
51. SUNESON, C. A. 1937: Emasculation of wheat by chilling. Jour. Amer. Soc. Agron. Vol. **29**, 247.
52. SUZUTA, I. and TOMURA, C. 1922: On the natural cross-fertilization in rice. (Japanese) Formosan Agric. Review No. **184**, 16.
53. TAKIGUCHI, Y. 1930: On the minimum temperature for blooming and seed setting in rice. (Japanese) Agric. and Hortic. Vol. **5**, 165.
54. THADANI, K. I. and DURGA DUTT, H. V. 1928: Studies on rice in Sind, Part I. Mem. Dep't. Agric. India, Bot. Series Vol. **15**, 113.
55. THOMPSTONE, E. 1915: Some observations on Upper Burma paddy. Agric. Jour. India Vol. **10**, 26.
56. TORRES, J. P. 1923: Some notes on rice hybridization work. Philippine Agric. Review Vol. **16**, 46.
57. TORRES, J. P. 1927: Some experience in rice hybridization. Philippine Agric. Review Vol. **20**, 261.
58. TSUJIKAWA, M. 1915: The blooming of rice flowers. (Japanese) Jour. Dainippon Agric. Soc. No. **405**, 65; No. **405**, 56.
59. YAMAGUCHI, H. 1935: On the blooming of wheat flowers in Formosa. (Japanese) Formosan Agric. Review No. **346**, 45.
60. YAMAMOTO, K. 1935: Technique of plant hybridization. (Japanese) Tokyo.

# APPENDIX

TABLE I.

Hourly temperatures in Plot 1 of Experiment XXXII. (°C)

(Lighted Continuously.)

| | June | | | | | | Average |
|---|---|---|---|---|---|---|---|
| | 16th | 17th | 18th | 19th | 20th | 21st | |
| 1 a.m. | | 25.7 | 25.6 | 25.7 | 24.8 | 25.1 | 25.4 |
| 2 a.m. | | 25.5 | 25.3 | 25.6 | 24.7 | 25.0 | 25.2 |
| 3 a.m. | | 25.4 | 25.2 | 25.4 | 24.6 | 25.0 | 25.1 |
| 4 a.m. | | 25.3 | 25.2 | 25.0 | 24.5 | 25.0 | 25.0 |
| 5 a.m. | | 25.1 | 25.2 | 24.9 | 24.3 | 24.9 | 24.9 |
| 6 a.m. | | 25.0 | 25.2 | 24.9 | 24.2 | 24.8 | 24.8 |
| 7 a.m. | | 25.0 | 25.2 | 24.9 | 24.3 | 24.8 | 24.8 |
| 8 a.m. | | 25.5 | 25.5 | 25.0 | 25.0 | 24.8 | 25.2 |
| 9 a.m. | | 26.0 | 26.0 | 25.5 | 25.5 | 25.0 | 25.6 |
| 10 a.m. | | 27.5 | 26.0 | 26.0 | 26.9 | 26.0 | 26.5 |
| 11 a.m. | | 28.5 | 27.0 | 26.0 | 27.0 | 26.5 | 27.0 |
| 12 noon | | 29.1 | 27.5 | 26.0 | 27.6 | 27.0 | 27.4 |
| 1 p.m. | | 29.0 | 27.3 | 26.0 | 27.9 | 27.5 | 27.5 |
| 2 p.m. | | 29.5 | 27.0 | 26.0 | 28.0 | 27.5 | 27.6 |
| 3 p.m. | 25.7 | 30.0 | 26.6 | 26.0 | 28.2 | | 27.3 |
| 4 p.m. | 26.0 | 29.1 | 26.5 | 26.0 | 28.3 | | 27.2 |
| 5 p.m. | 27.0 | 28.3 | 26.5 | 26.0 | 28.3 | | 27.2 |
| 6 p.m. | 26.9 | 28.0 | 26.5 | 25.8 | 27.8 | | 27.0 |
| 7 p.m. | 26.5 | 27.7 | 26.4 | 25.6 | 27.0 | | 26.6 |
| 8 p.m. | 26.1 | 27.2 | 26.3 | 25.3 | 26.0 | | 26.2 |
| 9 p.m. | 26.0 | 27.0 | 26.1 | 25.1 | 25.8 | | 26.0 |
| 10 p.m. | 25.9 | 26.6 | 26.0 | 24.9 | 25.7 | | 25.8 |
| 11 p.m. | 25.8 | 26.0 | 25.9 | 24.8 | 25.4 | | 25.6 |
| 12 midnight | 25.7 | 25.8 | 25.8 | 24.8 | 25.2 | | 25.5 |

TABLE II.

Hourly temperatures in Plot 1 of Experiment XXXV. (°C)

(Lighted Continuously.)

| | October | November | | | | | | Average |
|---|---|---|---|---|---|---|---|---|
| | 31st | 1st | 2nd | 3rd | 4th | 5th | 6th | |
| 1 a.m. | | 24.8 | 25.6 | 25.1 | 25.0 | 24.6 | 24.7 | 25.0 |
| 2 a.m. | | 24.7 | 25.4 | 24.9 | 24.8 | 24.2 | 24.0 | 24.7 |
| 3 a.m. | | 24.4 | 25.1 | 24.6 | 24.5 | 23.6 | 23.6 | 24.3 |
| 4 a.m. | | 23.9 | 25.0 | 24.4 | 24.0 | 23.4 | 23.1 | 24.0 |
| 5 a.m. | | 23.7 | 24.8 | 24.0 | 23.6 | 22.5 | 22.9 | 23.6 |
| 6 a.m. | | 23.6 | 24.7 | 23.5 | 23.1 | 22.5 | 22.8 | 23.4 |
| 7 a.m. | | 23.0 | 24.3 | 23.0 | 22.9 | 22.4 | 22.5 | 23.0 |
| 8 a.m. | | 24.0 | 24.3 | 22.8 | 22.5 | 22.8 | 23.0 | 23.2 |
| 9 a.m. | | 26.0 | 25.7 | 24.7 | 25.0 | 24.5 | 25.3 | 25.2 |
| 10 a.m. | | 29.0 | 26.2 | 27.0 | 28.0 | 27.7 | 28.0 | 27.7 |
| 11 a.m. | | 30.5 | 29.0 | 29.6 | 30.6 | 29.3 | 30.2 | 29.9 |
| 12 noon | | 32.0 | 30.0 | 31.0 | 32.2 | 30.9 | 32.0 | 31.4 |
| 1 p.m. | | 32.3 | 31.1 | 31.7 | 33.1 | 31.7 | 32.6 | 32.1 |
| 2 p.m. | | 32.5 | 31.4 | 31.9 | 33.6 | 31.9 | 32.5 | 32.3 |
| 3 p.m. | | 32.0 | 30.9 | 31.1 | 32.0 | 31.5 | 31.0 | 31.4 |
| 4 p.m. | | 31.0 | 30.2 | 30.6 | 31.3 | 30.8 | 29.6 | 30.6 |
| 5 p.m. | | 29.5 | 29.4 | 30.0 | 30.2 | 30.0 | 28.5 | 29.6 |
| 6 p.m. | | 28.5 | 28.5 | 28.7 | 29.0 | 28.9 | 27.1 | 28.5 |
| 7 p.m. | | 27.4 | 27.0 | 27.4 | 28.0 | 27.8 | 26.5 | 27.4 |
| 8 p.m. | | 26.8 | 26.4 | 26.6 | 27.2 | 27.3 | 26.0 | 26.7 |
| 9 p.m. | | 26.5 | 26.2 | 26.1 | 26.8 | 26.7 | 26.0 | 26.4 |
| 10 p.m. | | 26.2 | 26.0 | 25.9 | 26.0 | 26.3 | 26.0 | 26.1 |
| 11 p.m. | 25.5 | 26.0 | 25.8 | 25.6 | 25.5 | 25.5 | | 25.7 |
| 12 midnight | 25.1 | 25.8 | 25.5 | 25.2 | 25.0 | 25.0 | | 25.3 |

TABLE III.

Hourly temperatures in Plot 2 of Experiment XXXII. (°C)

(Darkened in the daytime and lighted at night.)

| | June | | | | | | Average |
|---|---|---|---|---|---|---|---|
| | 16th | 17th | 18th | 19th | 20th | 21st | |
| 1 a.m. | | 24.6 | 25.3 | 25.4 | 24.5 | 24.7 | 24.9 |
| 2 a.m. | | 24.7 | 25.2 | 25.3 | 24.4 | 24.5 | 24.8 |
| 3 a.m. | | 24.7 | 25.2 | 25.2 | 24.0 | 24.5 | 24.7 |
| 4 a.m. | | 24.7 | 25.2 | 24.9 | 24.0 | 24.4 | 24.6 |
| 5 a.m. | | 24.7 | 25.1 | 24.8 | 24.2 | 24.3 | 24.6 |
| 6 a.m. | | 24.6 | 25.0 | 24.6 | 24.1 | 24.3 | 24.5 |
| 7 a.m. | | 24.5 | 24.9 | 24.5 | 24.0 | 24.1 | 24.4 |
| 8 a.m. | | 25.0 | 24.9 | 24.5 | 24.3 | 23.9 | 24.5 |
| 9 a.m. | | 25.5 | 25.0 | 25.0 | 24.6 | 24.0 | 24.8 |
| 10 a.m. | | 27.0 | 25.1 | 25.5 | 25.3 | 24.8 | 25.5 |
| 11 a.m. | | 27.5 | 25.5 | 25.5 | 25.8 | 25.0 | 25.9 |
| 12 noon | | 28.0 | 26.4 | 25.5 | 26.5 | 25.7 | 26.4 |
| 1 p.m. | | 28.1 | 26.1 | 25.1 | 26.8 | 25.9 | 26.4 |
| 2 p.m. | | 28.5 | 25.9 | 25.0 | 26.9 | 25.9 | 26.4 |
| 3 p.m. | 25.0 | 28.9 | 25.7 | 25.2 | 27.0 | | 26.4 |
| 4 p.m. | 25.2 | 28.3 | 25.6 | 25.3 | 27.0 | | 26.3 |
| 5 p.m. | 26.3 | 27.5 | 25.6 | 25.5 | 26.8 | | 26.3 |
| 6 p.m. | 25.7 | 27.1 | 25.5 | 25.5 | 26.5 | | 26.1 |
| 7 p.m. | 25.5 | 27.0 | 25.6 | 25.3 | 26.1 | | 25.9 |
| 8 p.m. | 25.4 | 26.8 | 25.6 | 25.0 | 25.7 | | 25.7 |
| 9 p.m. | 25.3 | 26.6 | 25.6 | 24.9 | 25.4 | | 25.6 |
| 10 p.m. | 25.1 | 26.4 | 25.6 | 24.7 | 25.3 | | 25.4 |
| 11 p.m. | 25.0 | 25.8 | 25.5 | 24.5 | 25.0 | | 25.2 |
| 12 midnight | 24.8 | 25.5 | 25.5 | 24.5 | 24.7 | | 25.0 |

TABLE IV.

Hourly temperatures in Plot 2 of Experiment XXXV. (°C)

(Darkened in the daytime and lighted at night.)

| | October | November | | | | | Average |
|---|---|---|---|---|---|---|---|
| | 31st | 1st | 2nd | 3rd | 4th | 5th | 6th | |
| 1 a.m. | | 24.0 | 24.4 | 24.3 | 24.6 | 23.9 | 23.9 | 24.2 |
| 2 a.m. | | 23.9 | 24.3 | 24.0 | 24.3 | 23.5 | 23.4 | 23.9 |
| 3 a.m. | | 23.6 | 24.0 | 23.9 | 24.0 | 23.0 | 23.0 | 23.6 |
| 4 a.m. | | 23.3 | 23.9 | 23.5 | 23.5 | 22.6 | 22.6 | 23.2 |
| 5 a.m. | | 23.0 | 23.9 | 23.0 | 23.1 | 22.1 | 22.3 | 22.9 |
| 6 a.m. | | 22.7 | 23.8 | 22.7 | 22.9 | 21.9 | 22.1 | 22.7 |
| 7 a.m. | | 22.5 | 23.6 | 22.3 | 22.4 | 21.7 | 21.9 | 22.4 |
| 8 a.m. | | 22.4 | 23.2 | 22.0 | 22.2 | 22.0 | 21.9 | 22.3 |
| 9 a.m. | | 24.3 | 24.0 | 24.0 | 25.0 | 24.0 | 24.2 | 24.3 |
| 10 a.m. | | 27.0 | 25.0 | 26.0 | 27.5 | 27.0 | 27.0 | 26.6 |
| 11 a.m. | | 28.1 | 26.8 | 28.0 | 29.0 | 28.8 | 28.3 | 28.2 |
| 12 noon | | 29.5 | 28.5 | 29.3 | 30.0 | 30.0 | 29.5 | 29.5 |
| 1 p.m. | | 30.3 | 29.0 | 30.4 | 31.1 | 31.1 | 30.4 | 30.4 |
| 2 p.m. | | 30.8 | 29.4 | 30.7 | 31.2 | 31.2 | 30.6 | 30.7 |
| 3 p.m. | | 30.3 | 29.3 | 30.1 | 30.5 | 30.7 | 30.0 | 30.2 |
| 4 p.m. | | 29.8 | 29.0 | 29.6 | 29.9 | 30.0 | 28.8 | 29.5 |
| 5 p.m. | | 28.4 | 28.1 | 28.1 | 29.0 | 29.0 | 27.5 | 28.4 |
| 6 p.m. | | 27.0 | 27.2 | 27.0 | 28.0 | 28.0 | 26.6 | 27.3 |
| 7 p.m. | | 26.1 | 26.0 | 26.0 | 27.0 | 27.1 | 25.9 | 26.4 |
| 8 p.m. | | 25.8 | 25.8 | 25.7 | 26.6 | 26.6 | 25.7 | 26.0 |
| 9 p.m. | | 25.5 | 25.5 | 25.4 | 26.0 | 26.0 | 25.7 | 25.7 |
| 10 p.m. | | 25.2 | 25.3 | 25.3 | 25.5 | 25.5 | 25.4 | 25.4 |
| 11 p.m. | 24.5 | 25.0 | 25.0 | 25.0 | 25.0 | 25.0 | | 24.9 |
| 12 midnight | 24.2 | 24.7 | 24.8 | 24.8 | 24.3 | 24.4 | | 24.5 |

TABLE V.

Hourly temperatures in the control plot of Experiment XXXII. (°C)

| | June | | | | | | Average |
|---|---|---|---|---|---|---|---|
| | 16th | 17th | 18th | 19th | 20th | 21st | |
| 1 a.m. | | 24.4 | 23.9 | 24.2 | 23.0 | 23.9 | 23.9 |
| 2 a.m. | | 24.3 | 23.9 | 24.0 | 23.0 | 24.0 | 23.8 |
| 3 a.m. | | 24.2 | 23.9 | 23.7 | 22.9 | 23.9 | 23.7 |
| 4 a.m. | | 24.0 | 24.0 | 23.1 | 22.9 | 23.9 | 23.6 |
| 5 a.m. | | 24.0 | 24.0 | 23.2 | 22.9 | 23.8 | 23.6 |
| 6 a.m. | | 23.9 | 24.0 | 23.8 | 22.9 | 24.0 | 23.7 |
| 7 a.m. | | 24.0 | 24.2 | 24.3 | 23.2 | 24.0 | 23.9 |
| 8 a.m. | | 24.2 | 24.7 | 25.0 | 23.7 | 24.2 | 24.4 |
| 9 a.m. | | 25.0 | 25.0 | 25.6 | 25.5 | 25.0 | 25.2 |
| 10 a.m. | | 26.9 | 25.0 | 25.2 | 25.0 | 25.6 | 25.5 |
| 11 a.m. | | 28.2 | 26.2 | 24.9 | 27.1 | 26.4 | 26.6 |
| 12 noon | | 29.8 | 27.7 | 24.9 | 27.7 | 27.0 | 27.4 |
| 1 p.m. | | 28.5 | 27.0 | 24.7 | 27.5 | 27.5 | 27.0 |
| 2 p.m. | | 30.3 | 26.4 | 24.7 | 28.0 | 27.0 | 27.3 |
| 3 p.m. | 26.1 | 30.0 | 25.9 | 24.7 | 28.0 | | 26.9 |
| 4 p.m. | 25.3 | 28.5 | 25.8 | 24.7 | 27.1 | | 26.3 |
| 5 p.m. | 26.0 | 27.2 | 25.8 | 24.0 | 26.5 | | 25.9 |
| 6 p.m. | 25.9 | 27.2 | 25.7 | 23.6 | 25.0 | | 25.5 |
| 7 p.m. | 25.5 | 27.0 | 25.4 | 23.2 | 24.3 | | 25.1 |
| 8 p.m. | 25.2 | 26.2 | 25.3 | 23.0 | 24.2 | | 24.8 |
| 9 p.m. | 24.8 | 26.0 | 25.3 | 23.0 | 24.1 | | 24.6 |
| 10 p.m. | 24.8 | 25.5 | 24.9 | 23.0 | 24.0 | | 24.4 |
| 11 p.m. | 24.6 | 24.0 | 24.7 | 23.0 | 24.0 | | 24.1 |
| 12 midnight | 24.5 | 24.0 | 24.4 | 23.0 | 23.9 | | 24.0 |

TABLE VI.

Hourly temperatures in the control plot of Experiment XXXV. (°C)

| | October | November | | | | | | Average |
|---|---|---|---|---|---|---|---|---|
| | 31st | 1st | 2nd | 3rd | 4th | 5th | 6th | |
| 1 a.m. | | 22.6 | 22.9 | 21.6 | 22.4 | 20.2 | 20.8 | 21.8 |
| 2 a.m. | | 22.0 | 22.6 | 21.4 | 22.2 | 19.6 | 20.0 | 21.3 |
| 3 a.m. | | 21.0 | 22.7 | 21.0 | 21.9 | 18.8 | 19.4 | 20.8 |
| 4 a.m. | | 20.5 | 22.7 | 20.2 | 21.0 | 18.2 | 19.0 | 20.3 |
| 5 a.m. | | 20.3 | 22.8 | 19.6 | 20.2 | 17.8 | 18.7 | 19.9 |
| 6 a.m. | | 20.2 | 22.4 | 19.0 | 19.4 | 17.3 | 18.3 | 19.4 |
| 7 a.m. | | 19.9 | 22.1 | 18.6 | 19.0 | 17.2 | 19.0 | 19.3 |
| 8 a.m. | | 22.8 | 23.8 | 21.0 | 21.6 | 20.0 | 21.1 | 21.7 |
| 9 a.m. | | 25.0 | 24.0 | 24.1 | 25.0 | 23.5 | 24.0 | 24.3 |
| 10 a.m. | | 28.0 | 26.3 | 26.3 | 27.8 | 28.0 | 27.1 | 27.3 |
| 11 a.m. | | 30.0 | 28.0 | 29.2 | 30.0 | 30.0 | 28.5 | 29.3 |
| 12 noon | | 30.8 | 28.6 | 30.5 | 31.1 | 31.0 | 29.3 | 30.2 |
| 1 p.m. | | 31.2 | 29.7 | 31.0 | 32.0 | 31.5 | 29.5 | 30.8 |
| 2 p.m. | | 30.6 | 30.0 | 31.0 | 31.3 | 31.4 | 29.0 | 30.6 |
| 3 p.m. | | 30.0 | 29.3 | 30.5 | 30.7 | 31.2 | 27.5 | 29.9 |
| 4 p.m. | | 29.0 | 28.3 | 30.0 | 29.5 | 30.8 | 26.3 | 29.0 |
| 5 p.m. | | 27.0 | 27.5 | 28.5 | 28.5 | 29.8 | 25.3 | 27.8 |
| 6 p.m. | | 25.3 | 25.8 | 26.2 | 27.3 | 27.5 | 24.8 | 26.2 |
| 7 p.m. | | 24.2 | 24.5 | 24.4 | 26.0 | 26.5 | 24.5 | 25.0 |
| 8 p.m. | | 24.0 | 23.8 | 23.6 | 24.5 | 25.2 | 24.3 | 24.2 |
| 9 p.m. | | 23.7 | 23.8 | 23.9 | 23.4 | 24.0 | 24.2 | 23.8 |
| 10 p.m. | | 23.3 | 23.7 | 23.9 | 22.7 | 23.0 | 24.2 | 23.5 |
| 11 p.m. | 22.6 | 22.7 | 23.0 | 23.5 | 21.8 | 22.0 | | 22.6 |
| 12 midnight | 23.0 | 22.5 | 22.2 | 23.2 | 21.0 | 21.4 | | 22.2 |

TABLE VII.

Hourly humidities in Plot 2 of Experiment XXXV. (%)

(Darkened in the daytime and lighted at night.)

| | October | November | | | | | | Average |
|---|---|---|---|---|---|---|---|---|
| | 31st | 1st | 2nd | 3rd | 4th | 5th | 6th | |
| 1 a.m. | | 79 | 78 | 80 | 78 | 79 | 81 | 79.2 |
| 2 a.m. | | 79 | 79 | 80 | 78 | 80 | 82 | 79.7 |
| 3 a.m. | | 80 | 80 | 81 | 79 | 80 | 82 | 80.3 |
| 4 a.m. | | 81 | 81 | 81 | 80 | 81 | 82 | 81.0 |
| 5 a.m. | | 81 | 82 | 81 | 80 | 81 | 83 | 81.3 |
| 6 a.m. | | 82 | 82 | 82 | 81 | 81 | 83 | 81.8 |
| 7 a.m. | | 82 | 82 | 82 | 81 | 81 | 84 | 82.0 |
| 8 a.m. | | 87 | 86 | 86 | 86 | 86 | 87 | 86.3 |
| 9 a.m. | | 87 | 86 | 88 | 87 | 87 | 88 | 87.2 |
| 10 a.m. | | 87 | 86 | 88 | 87 | 87 | 88 | 87.2 |
| 11 a.m. | | 83 | 85 | 86 | 83 | 83 | 85 | 84.2 |
| 12 noon | | 75 | 80 | 83 | 75 | 80 | 81 | 79.0 |
| 1 p.m. | | 70 | 78 | 73 | 67 | 73 | 75 | 72.7 |
| 2 p.m. | | 67 | 73 | 74 | 62 | 73 | 75 | 70.7 |
| 3 p.m. | | 71 | 74 | 75 | 70 | 73 | 76 | 73.2 |
| 4 p.m. | | 72 | 75 | 75 | 74 | 74 | 77 | 74.5 |
| 5 p.m. | | 72 | 75 | 74 | 75 | 74 | 79 | 74.8 |
| 6 p.m. | | 73 | 77 | 73 | 75 | 75 | 82 | 75.8 |
| 7 p.m. | | 74 | 77 | 74 | 76 | 76 | 84 | 76.8 |
| 8 p.m. | | 75 | 77 | 75 | 76 | 77 | 85 | 77.5 |
| 9 p.m. | | 75 | 78 | 75 | 76 | 78 | 85 | 77.8 |
| 10 p.m. | | 76 | 78 | 76 | 77 | 79 | 85 | 78.5 |
| 11 p.m. | 78 | 77 | 79 | 77 | 78 | 80 | | 78.2 |
| 12 midnight | 79 | 77 | 80 | 77 | 79 | 81 | | 78.8 |

## Organization of the Government Agricultural Research Institute

(May, 1940)

| | | |
|---|---|---|
| Director | Prof. | Kisaburo SHIBUYA, *Nogakuhakushi* |
| Secretary Office | | Moun RYU, Chief |
| Librarian | | Noboru YAMAMOTO |
| **Division of Crop Breeding and Agronomy** | | |
| Senior Agronomist | | Iwao KAMO, *Nogakuhakushi*, Chief |
| Senior Agronomist | Prof. | Eikichi ISO, *Nogakuhakushi* |
| Senior Agronomist | | Takao NAKAO |
| Senior Agronomist | | Hisao YAMAGUCHI |
| Junior Agronomist | | Shiro HAYASHI |
| Junior Agronomist | | Koichi SHIMAKURA |
| Junior Agronomist | | Hiroshi NISHIZAWA |
| Junior Agronomist | | Goshiro ICHIKAWA |
| Associate Plant Breeder | Prof. | Hitoshi KIHARA, *Rigakuhakushi* |
| Associate Plant Breeder | | Iwao SUZUTA |
| Associate Agricultural Engineer | Assist. Prof. | Tomotake TAKASAKA |
| **Division of Agricultural Chemistry** | | |
| Senior Agricultural Chemist | Prof. | Kisaburo SHIBUYA, *Nogakuhakushi*, Chief |
| Senior Agricultural Chemist | | Masayuki SHIMOTOMAI |
| Senior Agricultural Chemist | | Kikuo YAMAGISI |
| Senior Agricultural Chemist | | Itaru TUYUKI |
| Junior Agricultural Chemist | | Hisasi UTIYAMA |
| Junior Agricultural Chemist | | Kokken RIN |
| Junior Agricultural Chemist | | Hakaru ISHIMARU |
| Junior Agricultural Chemist | | Kazuo TAKAGI |
| Junior Agricultural Chemist | | Tositugu UEDA |
| Associate Agricultural Chemist | | Yasumi OGATA |
| **Division of Plant Pathology and Entomology** | | |
| Senior Entomologist | Prof. | Tokuichi SHIRAKI, *Nogakuhakushi*, Chief |
| Senior Entomologist | Prof. | Kanetomo ISSHIKI, *Rigakuhakushi* |
| Senior Entomologist | | Yushiro MIWA, *Nogakuhakushi* |
| Senior Plant Pathologist | | Yosio TOKUNAGA |
| Junior Entomologist | | Jinhaku SONAN |
| Junior Entomologist | | Ryoichi TAKAHASHI, *Nogakuhakushi* |
| Junior Plant Pathologist | | Masayuki OGAWA |
| Junior Entomologist | | Kei FUKUDA |
| Associate Plant Physiologist | Assist. Prof. | Kazuo GOTO, *Nogakuhakushi* |
| Associate Plant Pathologist | | Kaneyoshi SAWADA |
| Associate Entomologist | Assist. Prof. | Kiyoaki KOIZUMI, *Rigakuhakushi* |
| Associate Zoologist | Prof. | Bunichiro AOKI |
| Associate Botanist | | Hakumei FUKUYAMA |
| **Division of Zootechnics** | | |
| Senior Zootechnist | | Noriyoshi MAKITA, Chief |
| Senior Zootechnist | Prof. | Jinshin YAMANE, *Nogakuhakushi* |
| Senior Veterinarian | Prof. | Masaatsu SUGIMOTO, *Nogakuhakushi* |

Junior Zootechnist . . . . . Yukichi SAKIMOTO
Junior Veterinarian . . . . . Chusaburo SHOHO
Junior Zootechnist . . . . . Hideo ASANO

Division of Horticulture
Senior Horticulturist . . . . . Yoshiziro SAKURAI, Chief
Junior Agronomist . . . . . Goshiro ICHIKAWA

## Branch Stations

Shirin Horticultural Experiment Station, Shirin, Taihoku.
Senior Horticulturist . . . . . Yoshiziro SAKURAI, Chief

Heichin Tea Experiment Station, Heichin, Shinchiku.
Senior Agricultural Chemist . . . . . Kazuo HIGUCHI, Chief
Senior Agricultural Chemist . . . . . Ainosuke TANIMURA
Junior Agronomist . . . . . Kokitiro ARAI

Gyochi Black Tea Experiment Station, Gyochi, Taichu.
Senior Agricultural Chemist . . . . . Makoto FURUICHI, Chief
Senior Agricultural Chemist . . . . . Ainosuke TANIMURA
Junior Agronomist . . . . . Yutaka TADASA
Associate Engineer . . . . . Motoo TAKEUCHI
Associate Agronomist . . . . . Gen ZAIZEN

Kagi Agricultural Experiment Station, Kagi, Tainan.
Senior Agronomist . . . . . Sosaburo HIRAMA, Chief
Senior Agronomist . . . . . Hisao YAMAGUCHI
Junior Horticulturist . . . . . Toyochi KISHIMA
Junior Agronomist . . . . . Norihisa HASEGAWA
Junior Horticulturist . . . . . Shoichi HIRANO
Junior Entomologist . . . . . Kei FUKUDA
Junior Agronomist . . . . . Matsukichi SATO

Kagi Zootechnical Experiment Station, Kagi, Tainan.
Senior Zootechnist . . . . . Noriyoshi MAKITA, Chief
Junior Zootechnist . . . . . Suzushi KUROKI

Hozan Tropical Horticultural Experiment Station, Hozan, Takao.
Senior Horticulturist . . . . . Tsuneo EGUCHI, *Nogakuhakushi*, Chief
Senior Agricultural Chemist . . . . . Hideji SHIOIRI
Junior Horticulturist . . . . . Sajiro TSUGE
Junior Horticulturist . . . . . Nobuo KAMATA
Junior Agricultural Chemist . . . . . Takao SHINAGAWA

Koshun Zootechnical Experiment Station, Koshun, Takao.
Senior Veterinarian . . . . . Asataro KADONO, *Nogakuhakushi*, Chief
Senior Veterinarian . . . . . Yennosuke TATEZAWA
Junior Agronomist . . . . . Nariyoshi WADA
Junior Veterinarian . . . . . Hiyoshi TERADA
Associate Physician . . . . . Gyokushu RIN

Taito Tropical Agricultural Experiment Station, Taito, Taito.
Senior Horticulturist . . . . . Takao NAKAO, Chief
Senior Agronomist . . . . . Hisao YAMAGUCHI
Junior Agronomist . . . . . Hiroshi DOI
Junior Agricultural Chemist . . . . . Kazuo TAKAGI

昭和 15 年7月 24 日印刷
昭和 15 年7月 26 日發行

臺灣總督府農業試驗所
(臺北市幸町)
印刷人　顯川　首
臺北市大正町二丁目三十七番地
印刷所　株式會社 臺灣日日新報社
臺北市榮町四丁目三十二番地